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TECHNICAL SOCIETY

OF THE

PACIFIC COAST.

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ORGANIZED APRIL, 1884.

TRANSACTIONS.

ROOMS OF THE SOCIETY, 413 SUTTER STREET,

SAN FRANCISCO.

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a.c. Technical society of the Pacific coast

OFFICERS.

(use year number on back)

President.

COL. GEO. H. MENDELL, U. S. A.

Vice-President.

GEO. J. SPECHT.

Secretary.

CHARLES G. YALE.

Treasurer.

JOSEPH B. CROCKETT.

Directors.

MAJOR W. A. JONES, U. S. A. AUG. J. BOWIE, JR.
E. J. MOLERA, G. W. PERCY,
G. W. DICKIE.

Executive Committee:

GEO. J. SPECHT, AUG. J. BOWIE, JR., E. J. MOLERA.

Finance Committee:

G. W. DICKIE, G. W. PERCY, W. A. JONES.

Secretary's Address: CHARLES G. YALE, Secretary T. S. of P. C., 414 Clay street, San Francisco, Cal.

Treasurer's Address: J. B. CROCKETT, S. F. Gaslight Co., Howard and First streets, San Francisco, Cal.

Rooms of Society: DRUID'S HALL, 413 Sutter street, San Francisco, Cal.

Regular meeting nights, first Friday in each month. Hall open for members every Friday evening.

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UNIVERSITY OF ILLINOIS LIBRARY

LIST OF MEMBERS.

Adler, Emil .....4 California street,
Allardt, G. F.....418 California street.
Anderson, C. L.....419 California street.
Arents, Albert .....Hawthorne, Nevada.

Barendt, Arthur H.....526 Howard street.
Bassett, L. F.....Sacramento.
Behr, Hans C..... .. 217 Sansome street.
Behrnd, Gustav.....100 Jones street.
Bennett, A. A..... .. ..528 California street.
Bishop, F. A. .....1414 Post street.
Boschke, A.... .....934 Howard street.
Bowers, A. B.....528 California street.
Bowie, Aug. J., Jr.....217 Sansome street.
Bridges, Lyman.....702 Market street.
Browne, John D..... .... Bakersfield, Kern County, Cal.
Browne, Ross E.....University of California, Berkeley.
Brown, Frank E.....258 Market street.
Buckman, O. H.....Napa, Napa County, Cal.
Burr, E. C.....1224 Broadway street.

Carter, Charles W.....526 Howard street.
Clement, Lewis M .....1013 Central avenue, Oakland.
Clinch, Bryan I.....627 Kearny street.
Compton, H. T.....10 California street.
Crockett, Joseph B..... .....San Francisco Gaslight Co.
Crollard, Jules.....126 Kearny street.
Curtis, John M.....528 California street.
Curtis, W. G.....Central Pacific R.R., Townsend & 4th sts.
Curlett, William.....Phelan Block.
Cumming, David.....20 Fell street.

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Davidson, H. S.....
Deering, Michael..... 22 South Park.
d'Erlach, A.....1109 Twentieth street.
Dickie, G. W.....Union Iron Works.

Eckert, Ferdinand.....Pacific Rolling Mills.
Eckart, W. R.....217 Sansome street.

Fenner, Richard.....San Francisco Gaslight Co.
Fish, A. L.....30 First street.
Firth, J. Kirk.....Union Iron Works
Fitzhugh, J. B.....609 Polk street.

Gates, H. D.....301 Lombard street.
Gorrill, R. W.....4 California street.
Goldstein, F. M.....610 Commercial street.
Grunsky, C. E.....Sacramento, Cal.
Gutzkow, Fr.....18 Columbia street.

Hackett, John.....Oakland, Alameda County, Cal.
Hagemaier, Chas.....491 Haight street.
Hall, Wm. Ham.....Sacramento, Cal.
Hanscom W. W.....612 O'Farrell street.
Harbach, D L.....1713 Jones street.
Hendel, Chas. W.....La Porte, Plumas County, Cal.
Henkenius, Julius C.....610 Commercial street.
Herrmann, A T.....San Jose, Santa Clara County, Cal.
Herrmann, Chas.....San Jose, Santa Clara County, Cal.
Heynemann, L.....113 Pine street.
Hoadley, Milo.....2910 Bush street.
Hoffman, Chas. F.....418 California street.
Hodges, A. D, Jr.....22 California street.
Humphreys, T. H.....166 Ninth street.

Irelan, Wm., Jr.....Merchant's Exchange.

Janin, Alexis.....211 Sansome street.
Jennings, Hennen.....New Almaden, Santa Clara County, Cal.
Jenssen, F. H.....21 Dupont street.
Jones, Major W. A.....Presidio.

Kaufman, Chas.....Daggett, San Bernardino County, Cal.
Kern, A.....1057 Mission street.
King, M. G.....Oakland.
King, N..... Sacramento.
Kluegel, Chas. H.....1259 Webster street, Oakland.
Knox, Geo. C.....P. O. Box 849, Los Angeles.

Manson, Marsden .....10 California street.
Mason, John E.....3 6 Pine street.
Mauran, J. R.....610 Commercial street.
Melliss, D. Ernest.....508 Montgomery street.
Molera, E. J.....850 Van Ness avenue.
Mendell, Col. Geo. H.....533 Kearny street.
Moore, Robt. S.....Risdon Iron Works.
Morgan, T. W.....Oakland, Alameda County, Cal.
Minto, Wm.....Oakland, Alameda County, Cal.

Noble, Patrick .....Pacific Rolling Mills.

Oliver, Wm. Letts.....328 Montgomery street.

Pardy, George.....402 Montgomery street.
Percy, G. W.....318 Pine street.
Pierson, J. C.....Sacramento, Cal.
Pierce, G. L.....528 California street.
Poett, Alfred.....30 Laurel Place.

Quinan, Wm. R .....California Powder Works.

Ransome, E. L.....402 Montgomery street.
Reade, Frank.....New Almaden, Santa Clara County, Cal.
Reed, F. H.....1216 Chestnut street.
Rhodes, C. D.....710 California street.
Roessler, S. W.....533 Kearny street.

Sandow, George.....610 Commercial street.
Savage, R. H.....135 Fremont street.
Schierholz, A.....Risdon Iron Works.
Schuyler, James D.....610 Folsom street.

Shortt, L. H.....120 Sutter street.
Smith, Wm. P.....533 Kearny street.
Smyth, W. H. .....258 Market street.
Specht, Geo. J.....418 California street.
Spiers, James.....Fulton Foundry.
Stretch, R. H.....420 Montgomery street.
Stut, H.....811 Filbert street.
Sommer, Ad.....529 Market street.
Symington, R. B.....610 Commercial street.

Tasheira, Lewis.....506 Buchanan street.

Uhlig, Carl.....10 California street.

Vincent, H. P.....1402 Leavenworth street
Vischer, Hubert.....Carlin, Nevada.
Von Leicht, F.....418 California Street.

Wagoner, Luther.....317 Powell street.
Wepfer, G. W.....122 Bartlett street.
Wheeler, Harold.....522 Montgomery.
Williams, J. N. S.....1030 Pine street.
Wolfe, James E.....240 Montgomery street.
Wolfe, Geo. H.....240 Montgomery street.
Wolcott, C. C.....Mare Island Navy Yard.
Wright, John A.....318 Pine street.

Yale, Charles G.....414 Clay street.
Yorke, Edward, (deceased).....Sacramento, Cal.

FORMS.

[Form A.]

I, the undersigned, having been duly elected a..... of the Technical Society of the Pacific Coast, do hereby promise that I will be governed by the Constitution and By-Laws of said Society, as they are now formed, or as they may hereafter be altered, amended or enlarged; and that I will aid in advancing the objects of the said Society, and will attend the usual meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary for the time being, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this.....
day of.....18.....

[Form B.]

TECHNICAL SOCIETY OF THE PACFIC COAST,
SAN FRANCISCO,.....

SIR:

I have the pleasure to inform you that on the.....
day of.....you were elected a.....of the Technical Society of the Pacific Coast.

To confirm this election it is necessary for you, under Article XX of the Constitution, to subscribe the enclosed obligation, and pay to the Treasurer of the Society the prescribed fee, as stated in the enclosed bill.

Respectfully,
.....Secretary.

[Form C.]

TECHNICAL SOCIETY OF THE PACIFIC COAST,
SAN FRANCISCO,.....

SIR:

The Board of Direction of the Technical Society of the Pacific Coast has directed me to inform you that your annual contribution thereto has been in arrears since.....; the amount being.....and that, by the regulations of the Society, unless the same is paid within six months you will cease to be a member. I have, therefore, to request that you will order the payment thereof.

Respectfully,
.....Secretary.

APPLICATION.

The proposal for MEMBER, ASSOCIATE or JUNIOR, shall contain a statement, over the *candidate's signature*, of his *age*, *residence*, the nature and term of his *professional service*, and that he will conform to the requirements of membership if elected.

STATEMENT.

I [*Full Christian names and surname of candidate*] residing at [*City or town, county, State,*] being desirous of admission into the Technical Society of the Pacific Coast as [*State class of membership*] submit the following as my professional record:

I was born at [*Place of birth*] on [*Date of birth*] 18 , [*To embody for all classes of members, a concise narrative, with dates of the candidate's professional career, specifying the position he has held, the nature and extent of the works in or upon which he has been engaged, giving an idea of their magnitude and importance. All proper names, names of railroads, etc., must be written without abbreviation.*]

FOR MEMBER, ASSOCIATE OR JUNIOR.

I will conform to the requirements of membership, if elected as [*State class of memberhip.*]

[*The applicant will sign here his regular signature, and give his present post office address.*]

On the grounds stated and because we believe him from personal knowledge to be in all respects a proper person to be admitted into the Technical Society of the Pacific Coast, we hereby recommend [*Full name of candidate*] of [*Residence of candidate*] for election as [*Class of membership.*]

[*To be signed by at least three members of the Society, personally acquainted with the applicant.*]

[Nominations for Honorary Members may be made upon the preceding form of application, but Honorary Members are not required to present themselves as candidates; those making the nomination are to state the ground therefor. In using the form for this purpose, the word "I" will be omitted in the statement, the word "worthy" substituted for "desirous," and the word "we" inserted before the word "submit."]

[Blanks are furnished on application to the Secretary.]

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

UNIVERSITY OF ILLINOIS LIBRARY

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

Vol I.—March, April and May, 1884.

PRELIMINARY STEPS TOWARDS ORGANIZATION.

In February, 1884, some gentlemen of San Francisco connected with the engineering profession, in discussing the subject of a local engineering society, determined upon organizing one. In March a circular was issued, stating that a society would be formed, which would embrace military, mechanical, mining, gas, electrical and sanitary engineers, architects, assayers, metallurgists, chemists and manufacturers.

The objects of the society were stated in the circular to be "the professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of the technical profession in all its branches, and the establishment of a central point of reference and union for its members. Among the means to attain these ends shall be periodical meetings of the society, where questions concerning the entire profession will be discussed and acted upon. The special interests of the separate branches will be taken care of by a club, embracing only members of that particular branch—which club, however, will always remain a subordinate section of the general society. The proceedings will be published. It is believed that a society as above outlined will tend to give the

members of the profession the standing they deserve. A committee is now drafting a constitution and by-laws, which will be submitted to a general meeting for discussion and adoption, to be called as soon as the committee has finished its work."

The call for the formation of the society was signed by the following gentlemen: Geo. F. Allardt, C. E.; H. C. Behr, Mech. E.; Ross Browne, M. & C. E.; Aug. J. Bowie, Jr., M. E.; A Craven, C. E.; R. Fenner, Mech. E. San Francisco Gaslight Co.; J. Hagemaier, Mech. E.; A. D. Hodges, Jr., M. E.; Ch. F. Hoffman, M. & C. E.; J. E. Henkenius, C. E., U. S. Surveyor General's office; Fr. H. Jenssen, Chemist, Giant Powder Co ; M. Manson, C. E., Chief Engineer Harbor Commission; George Pardy, Patent Lawyer; W. Schroff, Architect; Geo. J. Specht, C. E.; P. Von Leicht, C. E.; H. P. Vincent, C. E.; and L. E. Wyneken, Architect.

A pamphlet containing the proposed constitution and by-laws was distributed to all interested, in order that suggestions might be made as to the best means of founding and conducting the society. Finally a call was issued for a meeting to be held in the library of the Mechanics' Institute on March 29th, 1884. This was the first meeting of the society.

PATENT ROOM MECHANICS' INSTITUTE LIBRARY, 27 POST ST.,
San Francisco, March 29, 1884.

Pursuant to the call, a preliminary meeting was held on this evening, for the purpose of perfecting a permanent organization. Some sixty gentlemen were present.

George J. Specht was chosen temporary Chairman, and Chas. G. Yale, temporary Secretary.

The Chairman stated the object of the meeting, referring to the circular which had called those present together.

The principal business of the evening was the consideration of a Constitution. A draft of a proposed Constitution had previously been submitted to all interested, in pamphlet form.

The Secretary then read the Constitution, section by section.

A number of changes were made in the different sections, to be incorporated in the revised copy.

A motion was adopted to appoint a committee of five to revise the Constitution as changed, and submit it at the next meeting. The following were placed in nomination for the committee: Messrs. Hall, Mendell, Wagoner, Bridges, Jones, Jennsen, Schuyler, Von Leicht, Specht, and Forsythe.

On ballot, the following were elected as Committee on Constitution: Col. Geo. H. Mendell, Wm. Ham. Hall, Maj. W. A. Jones, Luther Wagoner and F. Von Leicht.

On motion, the Chairman was added to the committee.

The meeting then adjourned to Saturday, April 5th.

ADJOURNED MEETING.

April 5th, 1884.

Mr. Geo. J. Specht acted as temporary Chairman. There were seventy gentlemen present.

The report of the committee on revision of the Constitution was read by Major Jones. An entirely revised Constitution was submitted, the changes decided on at the previous meeting having been incorporated therein. After some slight discussion, the Constitution, as read, was adopted.

The following agreement to join the Society was then signed by those present desiring to become charter members. On motion, it was decided to leave the roll open for signatures until April 12, at 8 P. M.

"We, the undersigned, do hereby declare ourselves as charter members of the Technical Society of the Pacific Coast, as organized this day, the fifth of April, 1884, at the meeting held at the library rooms of the Mechanics' Institute, 31 Post street, in the City and County of San Francisco, State of California, and we do hereby promise that we will be governed by the Constitution and By-Laws of said Society, as they are now proposed, or as they may hereafter be altered, amended or enlarged, and that we will aid in advancing the objects of said Society, and will attend the usual meetings thereof as often as we can conveniently, provided, that whenever we shall signify in writing to the Secretary for the time being, that we are desirous of withdrawing our

names therefrom, we shall (after payment of any arrears which may be due by us at that period) be free from this obligation."

"Witness our hand, this fifth day of April, A. D. one thousand eight hundred and eighty-four."

A motion was adopted to appoint a committee of five to draw up suitable By-Laws, and the Chair appointed Geo Pardy, Fr. Gutzkow, E. J. Molera, Lyman Bridges and Luther Wagoner.

Adjourned to Saturday, April 12th.

ADJOURNED MEETING.

April 12, 1884.

Geo. J. Specht, temporary Chairman.

Mr. George Pardy, of the Committee on By-Laws, read those framed by the Committee, which were, on motion of Mr. Allardt, adopted.

The Constitution and By-Laws were then adopted as a whole, as follows:

CONSTITUTION.

ARTICLE I.—*Name.*

The name of this Association is the TECHNICAL SOCIETY OF THE PACIFIC COAST.

ARTICLE II.—*Location.*

The permanent place for the transaction of the business of the Society shall be in the City of San Francisco.

ARTICLE III.—*Objects.*

Its objects are the professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of the technical professions, and the establishment of a central point of reference and union for its members.

ARTICLE IV.—*Means for Obtaining these Objects.*

Among the means to be employed in the accomplishment of these ends, shall be periodical meetings for the reading of papers and discussion of papers and questions pertaining to the technical professions, and the publication of the proceedings of the Society.

ARTICLE V.—*Eligible Members.*

All persons who are engaged professionally in the practical application of science shall be eligible for admission in the Society.

ARTICLE VI.—*Classes of Members.*

The Society shall consist of—

Members,
Honorary Members,
Juniors, and
Associates.

Each person when duly elected shall receive a certificate of membership.

A *Member* shall be one qualified to design as well as direct technical work, and who shall have been engaged professionally in the practical application of science for a period of seven years, or for a period of five years if a graduate of a college or technical school.

A person to be eligible as an *Honorary Member* shall be of acknowledged eminence in some branch of the technical profession and science.

A *Junior* shall be one who has had actual practice in technical work for a period of two years, or if a graduate of a scientific or collegiate institute for not less than one year.

An *Associate* shall be one who by reason of education or occupation is brought into active sympathy with technical subjects.

ARTICLE VII.—*Residents and Non-residents.*

Members and Juniors who reside within fifty miles of the City of San Francisco shall be deemed residents, and those who reside beyond this limit may, at their option, be deemed non-residents.

The membership of any person shall begin on the day of his election.

ARTICLE VIII.—*Right to Vote.*

Members only may vote. Honorary Members, Juniors and Associates shall have all the rights and privileges of membership, except that of voting.

ARTICLE IX.—*Application for Admission.*

Application for admission to the Society shall be endorsed by three members, who shall certify that they personally know the candidate and that he is worthy of acceptance. The application shall state, over the candidate's signature, his age, residence, and the nature of his qualifications. Applications of candidates for admission must be addressed to the Board of Direction, which shall approve or disapprove, and the candidates shall be balloted for as provided in the By-Laws. Seven negative votes shall exclude.

ARTICLE X.—*Subordinate Clubs.*

The members of the Society may form Subordinate Clubs, devoted to special branches of the technical professions.

The Clubs shall have the privilege of separate meetings for reading of papers and discussions, at times and places determined by themselves, but shall not assume to transact business in the name of the Society.

ARTICLE XI.—*Election of Honorary Members.*

Honorary Members may be elected upon the recommendation of the Board of Direction by a two-thirds vote of the members of the Society.

ARTICLE XII.—*Board of Direction.*

The Board of Direction shall consist of a President, a Vice-President and five Directors, who shall be elected from the members by written ballots by a majority of votes at the annual meeting of the Society. They shall be the Trustees of the Society. The Secretary and Treasurer shall be elected by ballot in the same manner and at the same time. Both, or either of them, may, or may not be members or directors of the Society.

The term of office shall begin at the close of the annual meeting and continue for one year, or until other officers are elected. Any vacancy occasioned by resignation or otherwise, must be filled at the next regular meeting of the Society after notice of said vacancy, by ballot and simple majority.

As far as reasonable and possible, the Board of Direction shall be so elected that all the different branches of the profession shall be represented.

ARTICLE XIII.—*Duties of the Board of Direction.*

The duties of the Board of Direction shall be to have general care of the affairs of the Society; to apply the funds in the Treasury, and to make at the annual meeting a report on the affairs of the Society, embracing the report of the Treasurer and an estimate of the probable expenses for the ensuing year.

The Board of Direction shall meet within one week after their election, and the first business shall be the appointment of two standing committees, one on "Finances," and one on "Executive Business," each consisting of three members of the Board of Direction.

The majority of the Board of Direction shall constitute a quorum.

ARTICLE XIV.—*Duties of the President and Vice-President.*

The President, or in his absence the Vice-President, shall preside at all meetings of the Society, and of the Board of Direction. In case of their absence, a President *pro tempore* shall be elected.

ARTICLE XV.—*Duties of the Secretary.*

The Secretary shall keep an accurate record of all the transactions of the Society and of the Board of Direction, shall issue all notices, shall attend to all the correspondence of the Society, and perform such other duties as the Board of Direction may deem proper.

ARTICLE XVI.—*Duties of the Treasurer.*

The Treasurer shall have charge of the funds of the Society, receive all moneys, and pay all bills and orders approved by the Chairman of the Finance Committee. He must report every three months to the Board of Direction, and at every annual meeting to the Society the state of the Society's finances. He shall deposit the moneys and invest the funds of the Society in its name and with the advice of the Board of Direction. He shall sign all checks.

ARTICLE XVII.—*Duties of the Finance Committee.*

The Finance Committee shall have supervision of the accounts of the Society; shall examine all bills and demands, audit the accounts of the Treasurer, and certify to his annual report.

ARTICLE XVIII.—*Duties of the Executive Committee.*

The Executive Committee shall have supervision of the rooms, printing, and of a library, in case such one be created by the Society; it shall decide upon the admission or non-admission of any subject for a lecture delivered before the Society; as well as the publication of such lectures or papers as may be presented to it.

ARTICLE XIX.—*Meetings of the Society.*

At any regular meeting of the Society, seven members shall constitute a quorum for the transaction of business. The Secretary shall notify all members of meetings of the Society, and of the nature of the business to be transacted thereat. The annual meeting for the election of officers and hearing the annual report shall be held on the third Saturday of January. The Board of Directors shall lay before this meeting a report of the state of the Society and of the subordinate clubs, together with a statement by the Treasurer, verified by the Committee on Finances, of the funds of the Society, the receipts and payments during the year ending upon the 31st of December preceding, and an estimate of the probable expenses for the ensuing year. This estimate shall be binding on the Society, unless a two-thirds vote of all members decides otherwise. Absent members can vote by letter.

ARTICLE XX.—*Entrance Fee and Yearly Dues.*

On being elected the candidate shall qualify by signing the Constitution and By-Laws, and by paying to the Treasurer of the Society the regular entrance fee and dues, before he can be entitled to receive his certificate of admission. If this be not done within sixty days from the notification of the election, said election shall be considered void.

ARTICLE XXI.—*Amount of Entrance Fee and Dues.*

The amount of entrance fee and dues shall be fixed at the annual meeting by majority of votes. Non-residents shall pay the full entrance fee, but only half the amount of the dues fixed for residents.

ARTICLE XXII.—*Refusal of Payment.*

Any person admitted to the Society who shall refuse to pay any dues, or who shall neglect the same for the term of twelve months after due notice is issued, shall cease to belong to the Society.

ARTICLE XXIII.—*Semi-annual Payments.*

Dues are payable in semi-annual installments, on January 31st and July 31st, and shall be paid in advance.

ARTICLE XXIV.—*Exemption from Payment.*

The Board of Direction may recommend to the next regular meeting an application for exemption from the payment of annual dues of any member, who, from ill health, advanced age, or other good reason, is unable to pay such dues; and the Board of Direction may, if so authorized by the vote of the regular meeting, remit the whole or part of dues in arrears.

ARTICLE XXV.—*Expulsion of Members.*

Upon the written request of ten or more members, that for cause therein set forth, a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there is sufficient reason, shall advise the accused that his resignation will be accepted. He may, upon demand, receive a copy of the charges against him, and present a written defense. Two months after such advice shall have been given the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a satisfactory defense made, shall then notify the member that he will be expelled in one month, unless he elects to appeal from this decision. Appeals shall be submitted to the Society by letter ballot In case no appeal be made, the Board of Direction shall expel the member, and notify him and the Society of the same, or of the action of the Society on appeal, and the above shall, in any event, be the only public announcement of the matter.

ARTICLE XXVI.—*Proposed Amendments to the Constitution.*

Proposed amendments to this Constitution must be submitted to the Board of Direction in writing, signed by not less than five members, on or before the first Saturday in November, and then communicated to the members of the Society at least twenty-five days previous to the annual meeting. Such amendments shall be in order for discussion and amendment at the annual meeting, and with such amendments thereto as may have been approved by a majority vote of the annual meeting, shall be voted upon by letter ballot, the vote to be counted at the first regular meeting in March. An affirmative vote of two-thirds of all ballots cast shall be necessary to secure the adoption of any amendment.

BY-LAWS.

ARTICLE I.—*Meetings.*

SECTION 1. The Annual and Election Meetings of this Society shall take place on the third Saturday of January of each year, as provided by Article XIX of the Constitution.

SEC. 2. The regular Stated Meetings of the Society shall be held on the first Friday of each month, at the Hall of the Society, at 7.30 P.M., from September 1st to the 1st of May, and at 8 P.M. during the remainder of the year.

SEC. 3. Special meetings of the Society may be called by the President on his own motion, or by him at the written request of at least seven members of the Society, setting forth the purposes in full of such meetings; but no other business than that stated in said call shall be transacted in any special meeting. The Secretary shall notify all the members, by mail, of such special meetings at least three days prior to the time fixed for said meetings.

SEC. 4. The Board of Direction shall meet once a month, or oftener, at such places and times as it may be convenient to its members, subject to the call of the President of the Society. The different clubs of the Society shall meet at their own pleasure, subject to the call of their respective presidents.

ARTICLE II.—*Nomination and Election of Officers.*

SECTION 1. The officers of the Society shall be elected by ballot, which may be sent by mail, inclosed in two sealed envelopes and directed to the Secretary of the Society; the outer envelope shall be indorsed with the voter's signature, and all such votes shall be counted on the first ballot for officers.

SEC. 2. At the December regular Stated Meeting a Nominating Committee of five members of the Society, not holding office, shall be appointed by the

members present at such meeting, and this Nominating Committee shall prepare and present to the Society on the Stated Meeting of the following January, a ticket naming one candidate for each office to be filled for the ensuing year, and thereupon this ticket shall be posted in a conspicuous place in the Hall of the Society and advertised in two or more of the San Francisco daily papers. Other tickets may be presented, and other candidates may be balloted for at the annual election meeting. At the January Stated Meeting two inspectors and two judges of election, who shall have charge of the ballot-box, shall be appointed. The ballot-box shall be kept open from 9 A.M. till 6 P.M., to receive the ballots of the members having the privilege of voting. and a register of those who vote shall be preserved. No member shall vote at the annual election who is delinquent in the payment of his dues for any portion of the preceding year. The ballot-box shall be sealed by the judges of election and opened by the President at the Annual Meeting of the Society. The judges shall then count the ballots cast for each candidate, and the candidate who shall receive a plurality of votes cast for the office for which he had been nominated shall be declared duly elected. Should two or more members of the Society receive the highest equal number of ballots for the same office, the members present at the annual meeting shall vote who amongst them shall be elected.

SEC. 3. At the annual meeting, after the result of the election has been declared, no other business shall be transacted before the ones specified in Articles XIX and XXVI of the Constitution.

ARTICLE III.—*Rules of Order.*

SECTION 1. The parliamentary rules, as laid down in Roberts' Manual of Parliamentary Law, shall be the rules of order in the transaction of business of this Society, except so far as these are modified by the Constitution and By-Laws.

ARTICLE IV.—*Order of Business.*

SECTION 1. At the monthly Stated Meetings the order of business shall be—

1st. Reading of the minutes of the previous meeting.
2d. Election and reception of new members.
3d. Propositions for membership.
4th. Donations.
5th. Written communications.
6th. Verbal communications.
7th. Reports of Committees.
8th. Reports of Officers.
9th. Unfinished business.
10th. New business.
11th. Adjournment.

ARTICLE V.—*Committees.*

SECTION 1. At the first meeting of the Board of Direction after the Annual Meeting, as provided by Article XIII of the Constitution, the Board of Direction shall appoint the "Finance" and "Executive Business" Committees. The "Executive Business" Committee shall provide sub-committees upon—

"*Books and Donations,*"
"*Lectures and papers to be read and discussed,*"
"*Branches of Science represented by the clubs.*"

Any member of the Society may be appointed to sub-committees. The sub-committees shall consist of no less than three members each.

SEC. 2. The sub-committee on "Books and Donations" shall have the charge of books, maps, papers, instruments, and all scientific objects. They shall recommend the acquisition or acceptance of all such objects to the "Executive Business" Committee.

SEC. 3. The sub-committee on "Lectures and Papers" shall receive from the Secretary all the papers presented to the Society to be read. It shall examine them and report to the "Executive Business" Committee whether such papers should be received, rejected or amended before being presented to the Society. They shall consult with the proper members of the clubs in matters special to branches of Science.

SEC. 4. The sub-committee on "Branches of Science" shall represent the Society in all technical matters submitted to the Society. They shall report to the Society any advancement made in their respective departments, and shall advise the sub-committee on "Lectures and Papers" when requested to do so.

ARTICLE VI.—*Membership.*

SECTION 1. The election of members shall take place after approval of the Board of Direction, as provided in Article IX of the Constitution. When approved, the name of the candidate as well as those of the members who have proposed him, written in blanks prepared to that effect, shall be posted conspicuously in a place at the Hall of the Society, provided for that purpose, from the monthly regular meeting in which his proposal shall be read to the Society, and which shall be the next following the meeting of the Board of Direction when his nomination was approved, to the following monthly meeting of the Society, when his election or rejection shall take place.

SEC. 2. The proposers of any rejected candidate may, within three months after such rejection, lay before the Board of Direction written evidence that an error was then made, and ask for a reconsideration of the proposal, which shall be granted on sufficient grounds, and if a ballot has been taken, another shall be ordered.

ARTICLE VII.—*Entrance Fee and Dues.*

SECTION 1. The amount of entrance fee and dues, until provided as per Article XXI of the Constitution, shall be as follows:

Resident Members,	$5	entrance fee;	$12	yearly dues.
Non-resident "	5	"	6	"
Resident Juniors,	5	"	9	"
Non-resident "	5	"	4 50	"
Associates,	5	"	12	"

Payable as provided in Article XX of the Constitution.

SEC. 2. All members and associates may be exempted from the payment of yearly dues, by an advanced payment of $100.

ARTICLE VIII.—*Professional Papers.*

SECTION 1. No papers shall be published under the auspices of the Society, unless read before it in one of its meetings.

SEC. 2 Papers shall be read before the Society in the order in which they have been approved by the "Executive Business" Committee, unless changed by consent of their authors.

SEC. 4. Every member and associate shall be entitled to one copy of all printed papers, published under the auspices of the Society. The authors of professional papers shall be entitled to twenty-five copies.

SEC. 5. No alterations in the papers read before the Society shall be made unless by consent of their authors.

SEC. 6. The Board of Direction, with the approval of the Society expressed at a Stated Meeting, may propose medals or prizes to be given to the authors of the best professional papers, on scientific subjects, proposed by the Society or the donors of the medals or prizes. The rules for the competition and award of the prizes shall be adopted by a committee appointed at the Stated Meeting in which the prizes were approved.

ARTICLE IX.—*Rules and Regulations.*

SECTION 1. The "Executive Business" Committee shall draft rules and regulations to be observed by all the members while in the Society's Hall. It shall provide a Visitor's Book, to register the names of all visitors, together with those of the members introducing them.

SEC. 2. It shall have power to impose fines to enforce such rules.

SEC. 3. Before the "Executive Business" Committee's rules and regulations go into effect, they must be read and approved by the Society in one of its Stated Meetings.

ARTICLE X.—*Amendments.*

These By-Laws may be amended at any regular meeting of the Society by the vote of the majority of the members present; *provided*, that at least seven votes be cast in favor of the amendments, and that notice of such proposed amendments shall have been presented in writing at the previous regular meeting.

It was announced by the Chair, that the number who had signed the roll was 126 Of these there were 61 civil engineers, 30 mechanical engineers, 12 mining engineers, 11 architects, 6 chemists and metallurgists, 4 surveyors and 2 patent attorneys.

In order to perfect the organization, it was resolved to first elect a permanent Secretary.

On motion of Major W. A. Jones, Charles G. Yale was elected permanent Secretary.

G. E. Allardt nominated for President, Col. Geo. H. Mendell.

On motion, the Secretary was instructed to cast a ballot for Col. Mendell, as President.

Marsden Manson nominated for Vice-President, George J. Specht.

On motion, the Secretary was instructed to cast a ballot for Mr. Specht as Vice-President.

C. G. Yale nominated Joseph B. Crockett for Treasurer.

On motion, the Secretary was instructed to cast a ballot for Mr. Crockett for Treasurer.

For Directors, the following nominations were made: Wm. Hammond Hall, C. E.; Aug. J. Bowie, Jr , M. E.; Geo. W. Percy, architect; E. J. Molera, electrician; Fr. Gutzkow, chemist; G. W. Dickie, mechanical engineer; Patrick Noble, mechanical engineer; Major W. A. Jones, military engineer; W. G. Curtis, railroad engineer.

Messrs. Von Leicht and Wagoner were appointed tellers, and reported the following elected Directors:

Major W. A. Jones, Aug. J. Bowie, Jr., E. J. Molera, Wm. Ham. Hall and G. W. Percy.

On motion, of Mr. Wagoner, it was resolved to call the roll in order to determine how many members of the Technical Society of the Pacific Coast were also members of the Mechanics' Institute.

Mr. Hanscom, after some discussion, moved to reconsider the resolution, which motion was carried.

Mr. Wagoner again made the motion to call the roll to ascertain how many members of the Society also belonged to Mechanics' Institute. There was a tie vote, and the President declared the motion lost.

On motion of Major Von Leicht, it was resolved to print the Constitution, By-Laws and list of members, and the Secretary was instructed to send a copy to the library of the Mechanics' Institute.

A vote of thanks for use of rooms was passed to the Mechanics' Institute, and the Secretary instructed to forward a copy.

Adjourned to first Friday in May.

HALL OF SOCIETY, 413 SUTTER STREET.

May 2d, 1884.

President Mendell in the chair.

The reading of the minutes was dispensed with, and the "Reports of Officers" taken up in the order of business.

The President directed the Secretary to read the resignation of Wm. Ham. Hall from the Board of Direction, which had been accepted by the Board.

On motion of Major Jones it was resolved to fill the vacancy in the Board, and confine the nomination to mechanical engineers.

Mr. Bowers nominated G. W. Dickie, who was unanimously elected as Director, *vice* Wm. Ham. Hall, resigned.

The Executive Committee reported having engaged the hall at No. 413 Sutter street, for Friday evenings during the year.

The President reminded the members that professional papers would be acceptable, and suggested that those who had any in course of preparation should report the titles to the Secretary.

A. B. Bowers gave notice of a proposed amendment to the By-Laws, as follows:

To amend Article 4 to read: "On the third Friday of each month the discussion of the paper or papers read at the previ-

ous stated monthly meeting shall be in order; and on the last Friday of each month the reading of communications on said papers shall be in order."

On motion of Mr. Hall, the following resolution was passed: "That the President be requested, under Section 3, Article I, of the By-Laws, to call one extra meeting on the third Friday of each month."

A paper was read by Wm. Ham. Hall on "The Sewage Question in California."

EXTRA MEETING.

May 16th, 1884.

Col. Geo. H. Mendell in the chair.

The President stated that notice had been sent to the members that on the request of Wm. Ham. Hall, who was compelled to be absent from the city, discussion on his paper "On the Sewage Question in California," was postponed till some other meeting.

Mr. Fr. Gutzkow gave a verbal description of the results of some experiments with the drying of substances by the exhaust steam from the engine. For some time he had been utilizing the exhaust steam in drying carbonate of magnesia at works in the vicinity of San Francisco. He suggested that by building suitable vats or tanks, and utilizing the exhaust steam in a certain way, ore might be dried in a more economical manner than is now done.

Rules in Reference to Papers to be Read or Published.

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1. The essays should be legibly transcribed on legal cap paper, on one side only. It is desirable that every paper be prefaced by a synopsis, not exceeding 1000 words in length. This synopsis may be printed in the Society's publications, in case the entire treatise, in the opinion of the Executive Committee, should not be printed.

2. Illustrations intended for publication should be drawn on tracing cloth, or white paper, with sharp, distinct and somewhat heavy lines, in the blackest Chinese ink, so that they can be photographed. No other colors are permitted. It is recommended that the dimensions of the drawing should be $7\frac{1}{4}''$ by $4\frac{1}{4}''$ or a multiple thereof. All drawings must be provided with a scale. All detail drawings must be sufficiently large to show all parts plainly, even when reduced by photography.

3. No paper will be accepted by the Executive Committee to be read at a regular meeting, or to be published in the transactions of the Society, which has been read at the meeting of other societies, or has been published in any form.

4. All papers and communications must be received by the Secretary, at least ten days in advance of the meeting at which they are intended to be read.

5. All papers and discussions thereon, presented to the Society, shall be considered the property thereof.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE SEWAGE QUESTION IN CALIFORNIA.

By WM. HAM. HALL, M. T. S. of P. C.

Read May 2, 1884.

INTRODUCTORY.

The question of the disposal of sewage is one which has been considered as a leading problem by scientific societies of many different types, on a number of occasions during the past thirty years, and is yet a favored topic for technical discussion.

It is a many sided question, so that in some one of its aspects it is of special interest to the members in almost every group of practitioners in the field of technology; hence the author of this paper has thought it a peculiarly fitting subject to bring before this society, whose membership covers a wide range of technical practice.

Being the first paper before the society, and of course the first in this line, the author endeavors, by reviewing the subject in its leading points, to present the problem in its entirety rather than to elaborate any branch of it with the details of technology relative thereto; leaving such details to be brought out in discussion or in other papers, each devoted to some branch of the subject.

THE SEWAGE QUESTION.

The term SEWAGE QUESTION applies to the problems of final disposal of sewage matter and sewage.

The name "sewage matter" applies to all refuse organic substances which are or may become noxious, and which accumulate as wastes in or about establishments under human control.

The name "sewage matter" also applies to all waste sub-

stances carried along or mixed with, held in suspension or solution by sewage waters, as polluting substances which are or may of themselves become noxious, or which have been made noxious by admixture with other sewage matter.

The name "sewage" applies to waste waters with their burden of sewage matters from establishments under human control.

The name "sewage water" applies to the water which, with the polluting wastes, composes the sewage.

The term "final disposal" contemplates the disposition of the sewage matter and sewage in some way unobjectionable from any cause, alike to the locality sewered, to other localities and to the public generally.

The Dry Wastes of Cities and Towns.—I first mention the matters commonly removed by scavengers; of these, stable litters and manures generally are disposed of in manuring soils. When applied with any reasonable degree of care, this means of disposal is, from a sanitary point of view, of course, unobjectionable, and economically it is commendable. Yard scrapings and street sweepings are frequently disposed of in the same manner, with equal propriety and benefit. All of these substances, however, are often used for grading up low grounds, within the confines of territory afterwards to be closely built upon.

This practice, in its influence on human health, is unquestionably a pernicious one, and should not be permitted. Organic matter, both vegetable and animal, is thus piled into deep heaps, where it cannot be aerified and kept in a dessicated state while becoming oxidized, and consequently it slowly decomposes under conditions most favorable for the generation of noxious gases and vapors, the harboring or development of disease germs, and the poisoning of the atmosphere underneath and around the habitations or establishments built over or near it.

The ground we build on and walk upon is a vast lung; alternately exhaling air and gases from its pores, as those pores become filled with water—water from the surface or from below—and inhaling air to fill its intermolecular and percolative spaces, as the water is drained or evaporated away. We cannot poison

the ground upon which we live, or transact business, or take exercise and pleasure, with organic matter, without, to some extent at least, poisoning the atmosphere that comes in contact with the ground, and which we breathe. This is a matter of broader significance and graver import than the scope of this subject will admit of consideration, but in so far as the disposal of the classes of matter we are now treating of is concerned, *they* certainly ought to be otherwise treated than by use in filling streets and town lots.

Kitchen garbage, market stand refuse and slaughter house offal, comprise a more noxious class of matter, also generally removed by scavengers from the confines of the larger towns and cities of the more civilized peoples. To a considerable extent these substances are frequently made economically available as food for animals and poultry; and when thus disposed of at suitable places with due care and promptness, we cannot on sanitary grounds relevant to the protection of the purity of the atmosphere, condemn the practice. It is not an uncommon thing, however, to see large masses of even some parts of these substances used in filling low grounds within city or town limits.

The objection urged to this method of disposal for stable manures and the scrapings of streets and yards, of course applies to similar disposal for garbage, with far greater force. It matters not that they are frequently mixed with ashes and dry earth and dust. If they are put in heaps or deep fillings, where subject to alternate moisture and dryness, or to moisture alone, the decomposition goes on and the sanitary condition of the immediate neighborhood is deteriorated, and in most cases very materially so. It is to be remembered here that the harm chiefly makes itself apparent when the land thus filled in is occupied by streets and buildings. The danger is not so great when the sun and air more freely get at the surface of the dump piles, but when paved streets and yards occupy a large part of the surface, the earth breathes through the basements and cellars and foundation area of the houses, and the effect of the decomposition going on is concentrated at localities and at certain times, thus the more certainly producing its baneful influences.

Not only has observation of modern experiences shown the

wisdom of fearing such places for habitation or occupation, but it is held by well informed sanitarians that the most unhealthful spots of the old world, the plague spots, are over the sites of extinct cities, where organic matter has lain decomposing for centuries in the past, and is still giving forth its deadly miasms.

Stable manure and litter, yard scrapings, street sweepings, and some portions of garbage, may be used as fillings or dressings on agricultural lands, if not deposited at one time in great depths, or if properly plowed in or turned up to the air, but garbage generally and refuse from slaughter houses, and such like matter, must be more rapidly treated for its oxidation or other final disposal.

In the case of all this class of matters, prompt removal and the rapid oxidation and destruction or perfect dessication of the organic tissues composing their noxious parts, is the object to be held in view, or else the deposit of them beyond their power for influencing the neighborhoods of human occupations, or waters for human consumption.

Sewage Matter Proper.—We now come to the consideration of the more noxious forms of sewage matter—those of the classes which ordinarily find their way into sewers when the water carriage system of house drainage and sewerage is fully developed in a city or town, and we are at once within the limits of the "Sewage Question" as generally discussed.

The primitive method in early biblical times of disposal of such of these matters as we are most familiar with, was by properly returning them to the earth. In later centuries, we know that the Romans, and perhaps other ancient peoples, had in some of their cities underground sewers through which, by the flow of water, the noxious wastes of human life and occupations were carried without the city limits. But when the world was emerging from the dark period of the middle ages, we know that the practice was to drop the vilest matters into pits in the ground, and to heap those whose presence could be tolerated, into piles on the ground's surface.

Cesspools.—The regard for outward appearance of cleanliness, which advancing civilization and refinement has brought about,

together with the economic tendencies of the peoples who suffer nothing to waste, has pretty much banished the filth piles from streets, courts, alleys, yards and cellars: the scavenger has effected that much for mankind. But, notwithstanding the writings of sanitarians, the preachings of medical men, and the general realization on the part of well-informed and refined people, as to the enormity of the evil accruing from the practice, the abodes of men are still amidst pits full of the foulest matter, poisoning the soil and the atmosphere around.

The *cesspool system* is dying a hard death. It will not give under. All sorts of devices are resorted to to avoid the only proper treatment of a cesspool, which is its utter and entire abolition.

The practice of depositing animal wastes in cesspools poisons the soil and pollutes the soil waters, and contaminates the air we breathe, and should be condemned and prohibited in every civilized community. There is an idea that a cesspool, surrounded and arched over by a water-tight wall, is not a very objectionable feature in a back yard. The foul matter is supposed to find its way out at the bottom, which is left open, and to be dispersed into the ground without harmful results. It is hardly necessary to say to this association that such an idea is fallacious.

Dry Systems.—As an advance upon the system of depositing human wastes in cesspools, various systems for the removal of such matter, together with that of other noxious refuse substances otherwise produced about human institutions, have, from time to time, been introduced. The characteristics of these systems of removal are relevant to the Sewerage and not to the Sewage Disposal Problems. The general idea has been to collect and transport the sewage matter away from the immediate neighborhood of the residences, towns and cities, for disposal elsewhere. The general systems of disposal have been to put it on to land or into water.

Methods of transportation have been, (1) in some receptacle, generally on wheeled vehicles; (2) in open or covered gutterways; (3) by closed sewers or pipes, wherein the matter flowed by gravity, or, (4) was forced by some artificial power.

When transported by vehicles, the noxious matters undiluted with water, have been directly or indirectly applied to land as manure, or deposited in water courses or large bodies of water to be carried away.

When moved in pipes by what is known as the Liernur Pneumatic system, also, the sewage matter is almost in the condition of production: that is, not much diluted by water But under all systems of sewerage other than the artificial transport by vehicles and the Liernur Pneumatic system, water is used as a transporting agent in such great volume as to materially increase the bulk of the resulting sewage, and complicate the problem of its disposal.

We have to consider, then, the disposal of this sewage matter (1) in small bulk but undiluted form, and (2) with water in comparatively large bulk and in varying proportions and degrees of dilution. When undiluted with water the more noxious matters are frequently mixed to a greater or less extent with dry earth, ashes or other dessicating agent, previous to removal. In this form they are usually applied directly to lands as a fertilizer, or are kept in compost heaps until needed and so used.

With moderate care in practice this method of disposing of sewage matter, in itself, is not objectionable on any sanitary ground; but, as ordinarily applied, very great causes for objection exist against the system of collection and removal themselves, on the ground of their producing disagreeable and unhealthful conditions of atmosphere in dwellings and elsewhere where the appliances are located. Where properly attended to, the dry earth system of disposal of human wastes has proven to be, in a very high degree, free from objection on sanitary grounds, but extreme regularity and thoroughness of attention is a necessary accompaniment to insure favorable results. Under circumstances where such attention can be secured, and where an abundance of suitable earth can conveniently be had, and where points for proper use of the removed matter are easily reached, this system is in some lights an excellent one. It provides very fully for the disposal of all human wastes, but the slops of the kitchen and other household establishments have to be otherwise disposed of, and hence the dry earth system is far

from complete as a sewerage system; and hence, however carefully and completely it may be administered, it does not solve the general sewage disposal problem, seeing that it only deals with one class of sewage matter.

Applied in isolated dwellings or institutions, or in small villages or towns, or rural neighborhoods, where waste waters and slops may be disposed of by application to soils near the points of production and thus be eliminated from the problem of removal, the dry earth system for the treatment of human wastes may serve a very useful purpose, and for the locality, solve the sewage disposal problem; otherwise applied, it does not. It cannot be successfully operated in the case of a considerable city.

Other systems of sewage matter removal without water carriage, and without dessication and absorption of moisture by dry earth, as, for instance, the pail system, yet in vogue in many European cities, involve the deposit of the matter in a water-course or other body of water, a practice objectionable in the extreme under almost all circumstances, or the use of the matter directly or indirectly in the fertilization of land. When carefully conducted this last method of disposal, in itself, is not to be objected to on sanitary grounds; and, economically, it is praiseworthy.

All such systems, where dependent upon removal by means of vehicles, are decidedly objectionable upon the score of health and comfort, in the course of execution of the operation of collection and removal, and are open to the same objection as that urged against the dry earth system—namely, that they do not provide for the disposal of the waste waters and slops.

The Liernur system of sewerage effects the collection of the more noxious sewage matter, diluted in a small degree only with water, through pipes and by pneumatic pressure as a moving power, and contemplates its treatment chemically and mechanically for the concentration, drying and compression of the manurial solid ingredients into *poudrette*, for fertilizing purposes, the waters and liquids being disposed of as may be most convenient in each case.

Admitting, for the moment, the necessity in some instances for the collection and removal of the more noxious sewage matters by some dry system, it is sufficient to say that such removal

should be effected in air-tight carriers, and this matter thus removed should be used as manure on agricultural lands in a way to at once effect its deodorization and facilitate its dessication.

The Water Carriage System.—We now have come to the treatment of Sewage proper: that is, waste waters, with their burden of sewage matters.

The water-carriage system of sewerage came into existence by a gradual development; and, by reason of this very fact, several grave errors have been made, and the problem of disposing of such sewage has been greatly complicated Before there were such appliances as house drains and sewers, ditches or paved gutterways, generally along the centres of the roads or streets, carried away the surface drainage-waters. With the introduction of water into the houses came the production of large volumes of house slops, and the necessity for drains from the houses. Gradually the practice grew of disposing of the more noxious matters, particularly the liquids, through these drains. Of necessity the street gutters were now covered in. Open house drains gave place to underground boxes or stone drains. Covered street gutters gradually were changed to underground sewers. During this period of sewer development, the surface drainage waters were really in possession of the drainage ways as their own channels, and the sewage matter was a new element being gradually introduced. The surface drainage waters were largely depended on to keep the gutters and sewers flushed and clean, and hence their presence in the fully developed sewers was accepted as a matter of course, and as a presence beneficial and not to be dispensed with.

This practice has greatly complicated the sewage disposal problem of later years, for it has resulted, *first*, in the gradual growth of the practice of running sewage containing the most noxious matters in large volumes, into water courses, thus poisoning their beds and banks, and polluting their waters; and it has resulted, *second*, in the great increase of volume of sewage waters, over and above that necessary to carry off the sewage matter, and hence the production of sewage in volume so great at times as to defeat its disposal by any other process than that of running into streams.

Pollution of Waters.—The practice of the disposal of sewage by mingling it with the waters of rivers, tidal estuaries, etc., has been upheld upon the theory that running waters soon purify themselves.

Very much light has been thrown on this question by the investigations and controversies which have been had in England, where the subject has been most thoroughly examined.

It was alleged that the particles of the organic (animal and vegetable) parts of noxious matters, being dispersed by mingling with comparatively large bodies of water when dumped into a river or estuary, were brought in contact with the combined or dissolved oxygen of the air in the water, or of the air over the water, by the rolling or boiling motion of the current, and thus oxidized—a change equivalent in its effect to *burning.*

The theory appeared to be well founded. A number of instances were cited where the waters of streams polluted by sewage, apparently cleaned themselves by running a few miles. Others were brought forward where clear water streams polluted by peaty matter held in solution, became again clear after running similar short distances. These changes, it was said, were due to oxidation of the animal matter in the one case and the vegetable matter in the other; and hence, that the waters were purified And it was argued that contact with air under these conditions of mingling with water, having this effect of oxydizing organic matter in these cases, it would have such effect in all cases, and hence, the mingling of sewage with running or tide agitated waters was not a vicious and objectionable practice.

So well grounded has this theory appeared, and so strong were the interests involved in its favor, that in England, "until recently, sanitary engineers have done their best to remove sewage matter from towns into rivers in obedience to legislative requirements." (Bailey Denton, Lectures, etc., P. 248.)

But for years there has been the most violent opposition to this "pernicious and disgusting practice," throughout Western Europe, but more especially in England, where the subject has been forced to the front in ways that could not be ignored, and where the forms of laws and social organization appears to have

allowed wider range to the discussion than it attained in the other countries.

Facts soon proved that the theory of self-purification of river waters was at fault. Some streams of no less but greater volume, receiving no more or perhaps less sewage, did not purify their waters, as was alleged of others, and inquiry developed the fact that by no means all peaty waters become pure in their onward flow.

And most perplexing of all, it was observed that streams which for years had received sewage matter without much apparent detriment to their waters, became foul to every sense, within a comparatively short space of time, and without any considerable increase in the amount of sewage led into them.

In the mean time the attention of scientific men had been secured, and a store of systematically arranged facts was accumulating from observation and experiment. The aid of chemistry had been invoked, and waters were subjected to chemical analysis with comparatively satisfactory but sometimes startling results; for waters which had been regarded as pure, and which were so to all appearance, taste and smell, were shown to be laden with organic matter of a character calculated to develop the most deadly zymotic diseases under conditions favorable for such development. Some apparent cases of self-purification of streams were shown to be delusive; the waters were *clarified* and *deodorized*, but not *purified*, either of their organic impurities or inorganic elements not to be desired in potable waters.

The next step toward the truth, was the result of systematic studies into the causes of apparent self-purification of river waters in some instances, by which results the old theory of the oxidation of organic matters by contact with the air, and the consequent purification of river waters, as heretofore stated, is shown to have been an error.

It is now maintained that, *as a general thing*, waters polluted by the organic matter of sewage, do not purify themselves within any limited space of time, or distance of flow, as has been supposed, and in no material degree, by the sole action of the oxygen contained in the water, or of the air above it. It is certain that alleged cases of self-purification are only apparent to the

eye and sense of smell, and are not real; and it is contended that if waters are dangerous to health, they had better have the noxious appearance and smell, and thus carry with them a warning of their character, than be tempting to the eye or lulling in effect.

It is explained that the action of self-purification of rivers, of organic matter, found to take place in some cases, is due to the admixture from tributary streams or springs along their banks, of other waters having certain mineral substances (such as ferric oxides, copper and allumina) in solution, or to the action of certain clays which compose their bed or banks, and hence that such instances of self-purification are due to peculiar circumstances, which, being local and not generally distributed, establish the rule as against self-purification.

It is understood that the action of the soil of the banks or bed of a stream in purifying its water of organic matter, after awhile ceases, and that in the mean time the soil itself has become foul and poisoned to a degree that its effect upon the water, were *it* really purified above, would be to re-impart a noxious organic matter to it in a considerable degree.

Land the Purifier of Liquid Sewage.—It is to be remembered that the proportion of polluting matter in sewage is small as compared to that of the water; and that the object of all sewerage work should be to dispose of the noxious matter, so that at least it may do no harm, if, indeed, it be not made useful, and to restore the water to a state approximating purity. Cultivated land is the natural, as it is the best, practicable medium for the purification of the noxious matters which pollute the waters of sewage. Land of suitable soil, with prepared environments of locality and climate favorable, affords to judicious use all of the essential conditions under which the chemical changes necessary for the purification of sewage waters take place, in the most presentable form for the purpose that we can hope to find in practice.

In effecting the disposal of sewage, the immediate object to be held in view is to prevent decomposition or arrest fermentation, and thus forestall the development of organic germs, or the conditions under which they may be developed, the formation of gas and the giving off of foul odors.

A state of decided moisture being an essential condition to this process of decomposition or fermentation, and subsequent development, the removal of excessive moisture deprives the matter of the environment necessary to the baneful action.

And again, the action of the air upon the particles of matter is essential to the rapid change which it is desired to produce, and dispersion or separation of these particles is essential to the free access of the air.

In applying sewage to land under the conditions and in the manner heretofore spoken of as most favorable to a successful issue, the exact conditions are produced which best admit of those natural actions which we want to help along; the putrescible particles adhere to the granules of earth which absorb the moisture from them, arresting decomposition and holding them subject the action of the air, and thus effecting their oxidation; and finally, vegetation afterwards takes up the resultant matters, and so the change becomes complete.

From these considerations we see at once that conditions essential to the efficiency of this mode of disposing of sewage, are (1), a free, absorbing and well aerated soil, or at least, in each case, an application of sewage not in excess of the capacity of the soil, freely and promptly to absorb or take into its pores the liquid and suspended solid matters, without resulting in complete saturation, and without leaving a considerable scum or precipitate on the surface; (2), at least a fair depth to the soil; and (3), such under drainage, natural or artificial, as will promptly lead away superfluous moisture, and produce aeration of the soil; and, finally (4), cultivation of the soil and plant growth thereon, at least annually or at not distant intervals of time.

This question of sewage disposal has attracted a great deal of attention in England, and has been the subject of a number of practical and scientific investigations and inquiries, carried out under authority of law, or under the patronage of societies of arts or sciences. The author has diligently traced the course of these inquiries, in the original reports or publications, and wherever the question of the disposal of sewage has been the one at issue, and it has been fairly met, he has found the con-

clusion arrived at by such inquiries, to have been either unqualifiedly in favor of irrigation in all cases *where possible*, or in all cases where convenient. He has been unable to find one authoritative verdict against it. Differences of opinion are only in the degree of favor shown it, or as to the necessity of precipitating the solid matter before using the liquid on the land, or as to the area of land necessary for a fixed amount of sewage, or as to the economy of the plan of disposal.

Causes of Opposition to Irrigation.—Where the use of sewage waters in irrigation has failed to prove an efficient means of disposing of them, or of so far purifying them as to render them as fit to be put into rivers as the drainage waters from any highly cultivated, stocked, or manured farm lands, it is asserted upon the highest authority, and generally acceded to, that such result is due to one or more of five causes:

The quantity of sewage applied has been too great for the land irrigated.

The soil of the land has been radically unsuited for the purpose, or it has not been properly prepared.

The manner of application has been careless, or from other cause needlessly inefficient.

The land has been kept continuously in use for sewage purification, without cultivation and growth of crops, for too long a period of time; or—

The sewage itself has been exceptionably foul and full of putrescible matter, and has not been treated or defecated before application to the land.

The above causes of failure are such as, without proper knowledge and care, are liable to recur at any point where irrigation is resorted to as a means of disposal and purification of sewage, and of course are to be guarded against in the selection and preparation of lands, and the subsequent use thereof for the purpose.

England is a densely populated country; and land in the neighborhood of cities and towns has its prefixed uses, or actual or prospective value, far in excess of that which obtains here. So that it is difficult—sometimes almost impossible—to get sufficient land of suitable quality and favorably situated, to admit of the

adoption of irrigation as a means of disposal of the sewage of many towns and cities in that country.

Intermittent Downward Filtration.—To avoid this embarrassment, the process known as "Intermittent downward filtration," whereby lands were deeply underdrained, and used more as filter beds than as cultivated tracts with the view of disposing of a greater quantity of sewage upon the acre of land, was resorted to. It is alleged, by one school of sanitarians, that by this process the sewage of 1,500 people can be effectually disposed of, without nuisance, upon an acre of land, and it is claimed that in several places in England, the practice has run as high as 1,000 persons per acre. The principle is essentially the same as that of irrigation, with the absence, to a great extent, of the action of plant growth on the land; and the author has found no evidence amongst the mass, on the relative merits of broad (ordinary) irrigation and intermittent downward filtration, which inclines his judgment in favor of the latter, under circumstances where land is to be had for the former practice.

Climate of England not Favorable.—The climate of England is not such as to make artificial irrigation, with any water, on a broad scale for agricultural purposes, either necessary or very desirable, except for the special purpose of forcing grass on meadows, and for this use sewage waters are not altogether well adapted; and furthermore, English farmers are not an irrigating people, and would not contemplate irrigation except for the necessity of disposing of sewage waters. It will be seen at once that irrigation was undertaken there by reason of a motive engendered, as it were, outside of the necessities of agriculture—the irrigation was not demanded by the agricultural classes—but owing to the necessity under which the people living in towns rested, to dispose of their polluted waters, some agriculturists, from time to time, have been induced to undertake irrigation with sewage waters.

The Reform Movement.—Like all reforms much more was claimed for this than it justly deserved. It was claimed that

sewage contained vast amounts of fertilizing matters, which being applied to lands would greatly increase their productive powers; that farming with sewage would be exceedingly remunerative; that the farmer should pay for the privilege of using the sewage; and hence, it would be a source of revenue to the community producing as well as to the farmer using it.

Experience has shown that only under exceptionally favorable circumstances—and these circumstances are many and not often rightly combined—can anything more than the ordinary profit of farming be secured from the use of sewage in irrigation *in Great Britain;* and hence, that the communities producing the sewage cannot only not expect to derive a revenue from it, but generally speaking, must be at expense to assist in handling it, in order that the farmer may be compensated for the inconvenience to which he is put, or helped with the extra labor necessitated by its use; and beyond this, it is found advisable in some instances, where the available area of land is restricted, or its soil not suitable, or the sewage is of a specially noxious character, or for other reasons not necessary to be mentioned, to deprive the sewage waters of nearly all the matter carried in suspension by them before application is made to the land, thus involving the cost of works for the treatment of the sewage, and the expense of their maintenance and operation, which of course falls upon the community sewered.

The Sludge Complication.—And at this stage of the experience another sore disappointment, which has been general, made itself felt. It was represented, as an inducement to the municipalities to clarify their sewage waters, that the resulting solid manure would be of sufficient market value to more than cover the expense of the process, together with interest on the works. But this expectation also proved fallacious, and so it has transpired that irrigation is simply a method of purifying sewage waters, efficient in itself under ordinary conditions; that sewerage is a process of clearing filth from a town, and that "towns must pay to be clean," and cannot make capital of their offal, at least not in England.

Mechanical and Chemical Treatment.—The agitation against the practice of pollution of the rivers with sewage and manufacturing offal, taken up, as it was, by some of the most powerful associations and most accomplished individuals of England, was a very serious matter to many large moneyed interests in the country. The questions were carried into the courts, and in most cases decided in favor of the plaintiffs, and injunctions were issued restraining the town, or manufactory, as the case might be, from dumping its sewage into the stream.

There was great opposition to the adoption of irrigation as a means of disposal, for in fact, in many instances, as is alleged, it was simply impossible to get land enough for the purpose for the larger cities without pumping the sewage a number of miles, necessitating great expense for outfall and power works and annual charges for cost of operation.

Taking these facts into consideration, and the other circumstances that contribute towards making a sewage irrigation farm a troublesome and not a profitable property for a municipal corporation to handle in England, it is no wonder that many devices and processes have come to public notice, the owners or advocates of which claiming for them the power to do away with all the embarrassments of the problems of sewage disposal. In fact, such schemes may be numbered at least by hundreds.

Filtration was as first alleged to be the panacea for all evil caused by sewage and forthwith artificial filters of all conceivable patterns and compositions were designed and experimented with.

There was "upward filtration," where the liquid was forced upward through filters, leaving its heavier suspended matters below to be removed as "sludge," and there was "lateral filtration," where the filter was upright, as a partition or wall, and the liquid thus passed through from one tank to another; and again, "downward filtration," where the liquid passed downward by gravity through the filter-bed. And these filter-beds were composed of every conceivable material and combination of materials, ranging from gravel, coarse and fine, through coarse and fine sand, earths of various kinds, bone-

dust, wood charcoal, animal charcoal, thin boards with very small perforations, and many others besides.

The Rivers Pollution Commission tried some experiments upon the filtration of sewage through various soils, and they reported, in 1868, "that the process of filtration through gravel, sand, chalk, or certain kinds of soil, if properly carried out, is the most effective means of purifying sewage. (Rep. Riv. Pol. Com., 1868, p. 60.)

But this meant filtration through lands, and the fact is, as experience has proved also, that filtration cannot be "properly carried out" in an artificial filter, because it costs too much to make and maintain one large enough, so that the filter must be a natural one—a piece of land of such soil and subsoil composition as to be favorable, and either naturally or artificially well under-drained; and the process thus carried out is of course but one step—that of having a plant-growth on the land—removed from irrigation.

The advocates of artificial filter-beds for the purification, or the clarification, even, of sewage, have long ago abandoned their ground, and filtration now finds its place as a sort of concentration of irrigation, as heretofore spoken of under the heading of Intermittent Downward Filtration.

Precipitation.—The well known properties of alum, lime and alumina, whereby solid matters carried in suspension in water are made to settle to the bottom, where the fluid is in a moderate state of rest, were long ago availed of to extract the noxious matters from sewage, and a number of processes based upon the use of these precipitants, singly and in combination, in various proportions with each other, and a host of still other substances, have been devised, patented and tried—the most of them only to be discarded as worthless or too expensive in application.

The general method of treatment in nearly all processes of this class is, up to a certain point, the same; that is to say, the sewage is received in and passed through a series of tanks or reservoirs, being therein first screened to withhold the heavier, solid parts and the trash which finds its way into sewers, and then treated with the precipitating agents, generally referred to as "chemicals," either all at once or separately, as the liquid is

passed slowly by gravity from tank to tank in the series. The tanks vary in number according to the requirements of the special process to be employed, the thoroughness of treatment contemplated, and the volume of sewage to be treated, from three to as many as ten or twelve in some recorded instances; and they vary in capacity from a few hundred thousand to several millions of gallons each, according to the requirements of each case. They are sometimes constructed of iron, sometimes of masonry, sometimes of wood, frequently of earth, with or without concrete or other lining.

The precipitated matter called "sludge," after being cleared from the tanks, is variously dealt with and disposed of. In some instances it is immediately dug into lands as a raw, unprepared manure at or near the site of the precipitating works; in others, it is dried in the sun and sold to neighboring farmers as a manure; in others, it is dried artificially and prepared for shipment as a manure; in still other cases it is destroyed by burning; in one instance, at least, it is manufactured by burning into a cement; and so on, through a long list of cases, the processes and objects of its disposal are varied. The waters in a clarified condition after treatment—called the "effluent"—are sometimes permitted to pass immediately into the streams, or they are previously filtered in artificial filter-beds, or in natural filtering grounds, or are used, by some one of half a dozen or more methods, in irrigation; or finally, as in one case proposed at least, the "effluent" is to be converted into an illuminating gas

There are other processes by which manures are made direct from sewage, without passing it through a series of settling tanks. Larger quantities of chemicals, with screens and filters and presses are relied on in these methods, in connection with one or two tanks only, to remove and consolidate the manure matters.

Since the first recorded attempt at chemically clarifying or purifying sewage was made at Paris, France, over a hundred years ago, experiences have multiplied in this branch of technology by the hundred. France and Germany have had wide and varied experiences; Switzerland an extended one, but in Great Britain,

particularly England, perhaps the most extended and thorough trials and practical applications have been made, so that between the years 1856 and 1876 there were issued in England upwards of six hundred patents for different processes of clarifying or purifying sewage and disposing of the resulting "sludge" and "effluent" waters.

Undaunted by the repeated failures and the loss of millions of capital in experiments, immense projects of this kind are still in contemplation and process of development. Amongst these may be mentioned one for the treatment of the sewage of London, and another for the treatment of Paris sewage, by processes yet untried in actual practice, but which have proven encouraging enough upon experiment to secure the investment of large sums in works for their application.

Of the processes tried some appear to have given a measure of satisfaction under conditions where suitable land could not be obtained for irrigation, so that, without intending to specify any as very much better than the others, it may be well to review several which I find most prominently mentioned as having been submitted to practical trial, although it is alleged by some authorities that these all have failed, or are too expensive in application for general use, where it is desired to so far purify the sewage as to fit the effluent water for admission into any inland stream.

The *Coventry Process*, so called because of its adoption at the town of Coventry, in Warwickshire, employs salts of alumina as the chief precipitating agent. The sewage is first screened, to take out large floating solid matter, then treated to a dose of a solution of alumina, prepared in a cheap way by treating shale with sulphuric acid; then it receives a charge of milk of lime, and having dropped its solid matter in the tanks, the clarified water escaping from the tanks over weirs, is then conveyed to filter-beds where it is filtered, the beds being used alternately, and the water finally passes into the river.

The *Native Guano*, or A B C process, consists mainly in the use of alum, blood and clay as precipitants, the exact receipt embodying also magnesia, chloride of sodium, animal and vegetable charcoal and some other ingredients, and the manner of

application being in tanks. It has been tried at eight or ten large towns and cities with varying success, so far as economy and efficiency are concerned.

The *Phosphate Process* consists in the use of phosphate of alumina and lime as precipitants; the former being a good fertilizer, increases the value of the resulting "sludge" for manure and facilitates its sale. The phosphate of alumina is mixed with sulphuric acid to make it soluble; after which it is added to the sewage, together with a certain quantity of lime to aid the precipitation. This process also has had its application, and there are accounts of its success.

The *Lime Process* is about the oldest method of artificially treating sewage waters. At first, lime alone was used, but now some other ingredients are sometimes added. It has been tried in more places than any other process, and it may be said of it that whereas it fails to *purify* the sewage, it is a good clarifier, and perhaps fits the waters to be purified by application to land about as well as any of the more complicated manipulations; but it is complained of as not a good deodorizer during the operation, and as forming too much "sludge" of a low manurial value.

These are a few of a good many processes which may be found quite fully described in the report of the Rivers Pollution Commission, in special papers brought before the Society of Arts, the Institution of Civil Engineers, and the Association of Sanitary Engineers, and briefly described or alluded to in the works of Corfield, Robinson and Melliss, the report of Dr. Folsom, and elsewhere.

Taking them all together, the author finds it generally held by the authorities, and in fact most all who participate in the discussion, except those interested in the patent rights to the processes, or who want to adopt some such method of preparing sewage water for admission into a stream, to save a greater outlay for some other works, so far as he is able to judge, that they do clarify the liquid—precipitate the solid matter held in suspension; that some are decidedly more economical than others in the accomplishment of this result; that some, a few perhaps, accomplish more than a mere clarification, and remove matters held in solution; that economy here also is variable; and that

none of them so far *purify* the water as should render it admissible into a stream; but that it can readily be so purified by filtration through, or use in irrigation on a small area of land, after such clarification.

Conclusions.—Having now, in a general way, gone over the ground of sewage matter and sewage disposal, the author draws a number of primary and general conclusions from the lessons which experience elsewhere teaches, as follows:

1.—For sanitary and economic reasons, alike, all wastes and refuse of human existence or industries, known as "litter" or "rubbish," containing any considerable amount of organic matters, and produced within cities and towns, such as the sweepings of paved streets, the litter and manures from stables and cow-yards, except in so far as these may be used judiciously in fertilizing cultivated grounds, should be removed beyond the limits of probable urban occupation, and used in the fertilization of lands. In cases where from present financial reasons it is impossible to compass the proper disposal of this class of matter, it should be burned in special furnaces, and should not be suffered to remain within city or town limits.

2.—For sanitary and economic reasons, all refuse and waste substances, known as "garbage," composed almost exclusively of organic matters, and produced within cities and towns, should be promptly removed from the confines of urban occupation, and such portions as are not properly fed to animals, should be promptly dealt with for the enrichment of lands, or, for sanitary reasons, should be burned in proper furnaces, or cast adrift in the open sea or other large body of water, beyond the possibility of returning to the neighborhood of human habitations, or of contaminating water supply for human consumption.

3.—For sanitary reasons, all refuse and waste substances, of kinds not heretofore enumerated as "litter" or "garbage," produced within cities and towns, and known as sewage matter and as sewage, should be promptly removed therefron, by some system of carriage through pipe conduits, and should, for sanitary and economic reasons, be promptly and properly applied to prepared lands.

4.—In cases where, from financial embarrassment or physical cause, it is not possible thus to dispose of sewage on land.

(1) When an outfall may be had on a tide-swept sea coast, not in the immediate neighborhood of points of human occupation, the crude wastes may be conducted into the sea to a favorable point for outfall from the shore.

(2) When such sea coast outfall cannot be had, the sewage matter should be concentrated by mechanical or chemical means, and the sewage should be clarified by such means; the resulting concentrations should be prepared and used as manures on lands; the clarified liquids should be used in irrigating crops on lands, or filtered through prepared lands; or where these latter cannot be done, from the absence of suitable sites for such irrigations or filtrations, the clarified waters may be deposited in tide-swept bays, inlets or rivers of continuous flow and considerable volume.

(3) But sewage should never be conducted into any body of water, such as a river, except in the case of monster rivers approaching the Mississippi in volume, without previous clarification and purification by the best known means available in each case.

5.—The advantages and economies of living in towns are, in a measure, offset by disadvantages and economic embarrassments, amongst which is the necessity for the collection and distribution of a sufficient water supply for large bodies of people, and the corellative necessity for the removal and disposition of the polluted waters and waste substances; and that as towns must pay for water supply, so should they pay for the disposal of the sewage matter and sewage which they produce; they should not be permitted to dispose of their unclean wastes to the detriment of the country, of other towns or cities, of the public lands, or of the public waters.

Local Application of the Conclusions.—We have now come to a point where we may properly and intelligently look around at the conditions under which this sewage-disposal problem is coming up in California. The circumstances of climate, topography, hydrography, and density and condition of population, are the factors which affect the question in each locality as compared to other localities.

Recorded experiences with improved systems of sewage disposal have thus far chiefly been had in Great Britain, while some lessons are available from such experiences in France, Germany, and our Eastern States. With the old and defective systems the world is the field for observation, but more particularly have experiences been recorded in the above mentioned countries.

If sewage is to be used in irrigation, of course it can be thus disposed of to best advantage where irrigation is most needed.

The climate of Great Britain is one peculiarly unfitted for the practice of irrigation, and the soils generally are not favorable for cultivation by irrigation; so much so, that with the exception of irrigation of meadows for grass at a few notable localities, there are no irrigation examples of moment in the United Kingdom, except those brought about by the necessity for the disposal of sewage. Yet sewage is effectually and economically disposed of there by irrigation, notwithstanding this drawback of unfavorable climate and soil, and the other complicating circumstances which have been spoken of in the earlier part of this paper.

In Germany, even as far north as Berlin and Dantzig, with climate less favorable to irrigation the year round even than those of England, sewage disposal by irrigation is an established fact and a successful practice, directly encouraged by the government.

In France, with a climate more like our own, this method of sewage disposal has now been in successful operation for many years in the past.

In our own country, in Massachusetts, in New York, in Illinois and in Pennsylvania, are examples of successful treatment of sewage by irrigation.

Now, California, as compared to all the mentioned localities, is eminently an irrigation country. This is not alone true of those portions of the State where irrigation is an absolute necessity, and where it is being rapidly developed, but it is true of the whole agricultural area of the State, not excepting even the region of heavy rainfall in the northern coast counties, or the regions of snow and rainfall in the foot hills and lower mountain regions of the Sierras. We are to remember that our atmosphere

is peculiarly dry, and that our rains are delivered all in a certain half of the year, while the other half is almost absolutely without downpour.

These circumstances give us a climate making artificial irrigation a necessity for the production of very many classes of crops. And when the time comes that we have a population in our agricultural districts at all approaching in density that of England, France, or Germany, it will be found that our valleys, the most favored with rainfall even, will have to be irrigated to enable them to support the people.

The same circumstances of distribution of rainfall makes our hydrographical system a peculiar one. We have many streams which run only for a few weeks each season, except in years of exceptionally large rainfall, and all of our rivers have their long periods of excessively low rate of flow, unrelieved by summer freshets, which sweep out river channels in other countries. With the exception of the Sacramento, our rivers are all small streams for the greater part of each year; and many of them are for this dry period, quite insignificant in volume; and a number of others go almost entirely dry for several months each season. Their channels generally are through alluvial formations, their grades are not high, their velocities not particularly rapid at any time of year, and quite sluggish for the greater part of the time. With the exception of the San Joaquin and the small streams and sloughs about the principal bays, tidal movement is not sufficient in any of these rivers to cut any special figure in the movement of their waters in a way to materially assist in carrying off polluting matters. The tidal movement in our principal bays and their arms, is not nearly so great as in the firths and estuaries of the British coast, generally. These bays of California are much land-locked, and largely surrounded by mudflats and estuaries which the tidal movement do not effectively sweep, so that they are continually shoaling.

On the whole, our climate is one peculiarly adapted to the disposal of sewage in irrigation.

Our soils, as a general thing, are favorable to irrigation, and to the reception and purification of sewage waters. Our rivers generally are specially unfitted to receive and carry away or

purify sewage. Our bays and estuaries are not specially favorable, in form and tidal movement, to the reception and transmission to the open sea of the wastes of a dense population.

With respect to our future centers of population, we may conclude in general terms:

That in the interior of the State large cities will be situated on or near the Sacramento or San Joaquin rivers, but most of the large interior towns will not be either on or near any considerable water-course. The main centers of population will be around or in the neighborhood of San Francisco, San Pablo and Suisun bays, and in the valleys adjacent to the smaller streams tributary to these bays.

Taking these facts into consideration, I have no hesitation in predicting that the future will see the sewage of the interior towns and cities of California used in irrigation; that the sewage of many towns and neighborhoods in the bay districts will also be thus disposed of; that generally the sewage of the bay towns and cities will be treated chemically or mechanically for its clarification, and then put into the bays at the salient points in the shore lines, or elsewhere, where the tidal currents will be most favorably for carrying it away; and that only the sewage of such neighborhoods as can deliver it into the currents near the outlet of the harbor, as San Francisco, for instance, will be passed into the bays in a crude condition.

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NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

MEASUREMENT AND FLOW OF WATER IN DITCHES.

By AUG. J. BOWIE, JR., M. Tech. Soc.

Read June 6, 1884.

In California, where the rainfall over large portions of the State is small and periods of drought of not uncommon occurrence, the development of the agricultural as well as the mining interests, necessarily resulting from the continued influx of population, will be dependent greatly upon the careful husbanding of the water supply. The sources of this supply are comparatively limited, and the problem of systematic irrigation will grow daily in importance from the necessities of the farmers; and the demand for water will steadily increase with the more extended cultivation of the soil.

The costs of construction and maintenance of the necessary canals and ditches (depending principally on their capacity) will be of prime importance to the owners, who will appreciate fully the value of a correct determination of the flow of water. The easy-going farmer who purchases the water, will ultimately discover the necessity of knowing how much he is receiving, and then will come the demand for a standard of measurement of water.

The history of northern Italy, from the fourteenth to the eighteenth century, is replete with accounts of disputes and difficulties arising from the non-existence of some accepted standard of measurement of water. Similar troubles have arisen at times in the mining regions of this country, as can be attested by numerous court reports.

With the experiences of the past, and in consideration of the future interests of the country, it would seem advisable that some uniform gauge and standard of measurement of water should be adopted.

The miner's inch has only led to confusion and is the relict of the Mexican and Spaniard, who possibly took it from the Italian. Like the Italian oncia, which varied in nearly every province, so its brother the miner's inch has followed suit to even varying in the same district.

In the construction of the various water supply systems for the different placer regions in this State, certain experience in the measurement and flow of water has been acquired, and it has been considered of sufficient import to place some of the results of this work on record, with a view of assisting in clearing up the confusion about the *Miner's Inch*, and giving to those interested in the profession the benefits derived from the several works.

The Miner's Inch.—The Miner's Inch of water is a quantity which varies in almost every district in the State; no one gauge has been uniformly adopted, nor has any established pressure been agreed on, under which the water shall be measured. In some counties there are 10, 11 or 12-hour inches, and in others there is a 24-hour inch. The apertures through which the water is measured are generally rectangular, but vary greatly in width and length, being from 1 inch to 12 inches wide and from a few inches to several feet long. The discharges are through 1′, 1½′, 2′, and 3-inch planks, with square or with square and chamfered edges, combined or not, as the case may be. The bottoms of the openings are sometimes flush with the bottoms of the boxes, sometimes raised above them. The head may denote the disance above the center of the aperture, or again that above the top, and varies from 4½ inches to 12 inches above the center of the aperture.

The Smartsville inch is calculated from a discharge through a four-inch orifice with a seven-inch board top; that is to say, the head is seven inches above the opening, or nine inches above the center. The bottom of the aperture is on a level with the bottom of the box, and the board which regulates the pressure is a plank one inch thick and seven inches deep. Thus, an opening 250

inches long and four inches wide, with a pressure of seven inches above the top of the orifice, will discharge 1000 Smartsville miner's inches. Each square inch of the opening will discharge 1.76 cubic feet per minute, which approximates the discharge per inch of a two-inch orifice through a three-inch plank with a head of nine inches above the center of the opening, the said discharge being 1.78 cubic feet per minute. The Smartsville miner's inch will discharge 2534.40 cubic feet in twenty-four hours, though in that district the inch is only reckoned for eleven hours.

Other Inches.—The miner's inch of the Park Canal and Mining Company, in El Dorado County, discharges 1.39* cubic feet of water per minute. The inch of the South Yuba Canal Company is computed from a discharge through a two-inch aperture, over a one and one-half inch plank, with a head of six inches above the center of the orifice.

At the North Bloomfield, Milton and La Grange mines, the inch has been calculated from a discharge through an opening fifty inches long and two inches wide, through a three-inch plank (outer inch chamfered), with the water seven inches above the center of the opening.

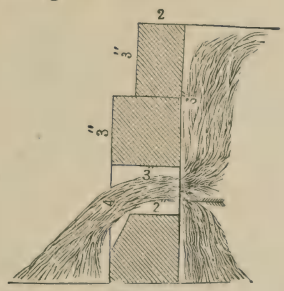

FIG. 1.

Determination of the inch experiments at Columbia Hill.—To determine the value of this miner's inch, a series of experiments was made at Columbia Hill, latitude 39 N., elevation 2900 feet above the sea-level. The *module* used was a rectangular slit fifty inches long and two inches wide; head seven inches above the center of the opening. The discharge was over a three-inch plank; the outer inch chamfered, as shown in Fig. 1.

*Estimated by J. J. Crawford, M. E.

The size of the opening was taken with a measure (micrometer attached), which had been compared with and adjusted to a standard United States Yard. Time was read to one-fifth of a second; the level of the water (drawn from a large reservoir) was determined with Boyden's hook, micrometer adjustment. The following results were obtained:

One Miner's Inch will discharge			in one sec.....	.026	cub. ft.
"	"	"	" min....	1.57	"
"	"	"	" hour...	94.2	"
"	"	"	in 24 hours..	2260.8	"

The coëfficient of efflux is 61.6 %. These figures are within the limit of $\frac{1}{50}$ possible error*.

As the two-inch aperture requires too much space for gauging large quantities of water, custom has changed the form of the module, and an aperture twelve inches high by twelve and three-quarters inches wide, through a one and one-half inch plank, with a head of six inches above the top of the discharge, is now used. These openings discharge what is accepted as 200 miner's inches.

A series of experiments was made at La Grange, Stanislaus County, California, latitude 37° 41′ N., elevation 216 feet above the level of the sea, to determine the value of the inch thus delivered in the claims. The results here given are the mean of a series of gaugings taken from nine different apertures, discharging in the aggregate 1,800 miners' inches.

The water was drawn directly from a flume and discharged into a small reservoir, across the lower end of which was fitted a gauge. The velocity of the water issuing from the flume was broken by several drops as it entered the reservoir, and the gauge at the lower end was raised sufficiently to prevent any flow due to an increased velocity which might have been acquired in the flume.

The level of the water was determined with a Boyden's hook.

The discharge from the module was caught in a flume and conducted to a box fitted and leveled for the purpose. Time was read to one-fifth of a second. The following results were obtained:

*The experiments were made in 1874, by H. Smith, Jr., C. E.

1 Miners' inch discharged in 1 second	.02499	cubic feet.
1 " " " 1 minute	1.4994	"
1 " " " 1 hour	89.9640.	"
1 " " " 24 hours	2159.1460.	"

Effective coëfficient of efflux, 59.05 per cent.*

An experiment on a single aperture of this form, made by Hamilton Smith, Jr., gave a discharge of 2179.4 cubic feet per miners' inch in twenty-four hours. The 2230 cubic feet of the North Bloomfield inch can only be considered an assumed rough estimate of discharge in 24 hours for 1 miner's inch.

The theoretical velocity in feet per second, of a fluid flowing into the air, through openings in the bottoms or sides of a vessel or reservoir, the surface level of which is kept constantly at the same height, is equal to that which a heavy body would acquire in falling through a space equal to the depth of the opening below the surface of the fluid, and is expressed as follows:

$$v=\sqrt{2gh}.$$

In which v=velocity in feet per second.
g=the acceleration of gravity.
h=the height fallen in feet.

This is called Torricelli's theorem, which supposes indefinitely small orifices with thin sides, and assumes that the upper surface of the water and the orifices are under the same conditions as regards atmospheric pressure. Conditions and size of sectional area of the aperture, friction, resistance of the air to motion and pressure of the atmosphere are all neglected.

The value of g varies in different latitudes, but for all practical purposes is taken as equal to 32.2.

$$\text{The theoretical head}=\frac{v^2}{2g}$$

The acceleration of gravity at latitude 45°=32.17 feet per second, being represented by g, for any other latitude, l.

$$g'=g\ (I-O.\ 002588\ cos\ 2l)\ \dagger$$

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*The experiments were made by the author.

† See professional papers, Corps of Engineers, U. S. A., No. 12, page 26.

If g represents the acceleration of gravity at the height, h and r the radius of the earth, the acceleration of gravity at the level of the sea equals—

$$g' = g\left(1 + \frac{5h}{4r}\right)$$

Flow of water in open channels.—There is no generally accepted formula for determining the velocity of water in open channels. The tables based on the old formulas published prior to the works of D'Arcy and Bazin, in France, and of Humphreys and Abbot, in the United States, being founded on data which ignore the important factor of the nature of the bed and the sides of the channel, have proved unsatisfactory. Hydraulic engineers have been compelled to rely for correctness of calculated result on the application of a combination of a few known laws with experimental data, which latter, though all important, have been too restricted for the deduction of reliable mathematical theory.

The formulas, in terms of dimensions of cross section and slope, are based upon the supposition of either "permanent" or "uniform" motion. Permanent motion approaches the condition of streams, permits changes of cross section and slope of the water surface, excepting sudden bends, causing eddies and undulations, but demands that the discharge from the different sections should be identical. Uniform motion, in addition, requires an invariable cross section and constant slope of the fluid-surface. The general formulas based on permanent motion, differ from those restricted to uniform motion, "by taking into account changes of living force produced by changes of cross section at the different points."* If these variations are unknown, the difference between the formulas disappears.

Chezy considered that the resistances encountered by water in uniform motion were in direct proportion to the length of the wetted perimeter, to the length of the channel and to the square of the mean velocity, from which he deduced the formula.

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* Humphreys and Abbot, Mississipi Report, p. 207.

$$v = c\sqrt{rs}.$$

v is the mean velocity in feet per second.
c a coëfficient taken at a constant value.
r the mean hydraulic radius in feet.
s the fall of surface in a unit of length.

The equation indicates the relation of the mean velocity to the slope and the mean hydraulic radius. The value of the coëfficient c has been demonstrated empirically to have a wide range. This formula, however, has been considered the simplest, and has been used by many engineers, different values being given to c, varying from 84 to 100 for large streams, and being as low as 68 for small streams. "Though there is abundant evidence," says Higham (p. 5), "that the latter is much too high for low values of v in earthen channels, and that 100 is too low for very large rivers, as high a value as 254.4 having been deduced from the Mississipi observations."

D'Arcy and Bazin, by their experiments on channels of moderate section with limited variation of grades, proved that the coëfficient c involved not only r and s, but also a constant for the different degrees of roughness of the channel, the formula being applicable within certain limits of inclination and values of r.

Humphreys and Abbot make the velocity vary with the fourth root of the inclination, while Hagen assumes the velocity to vary with the sixth root.

Ganguillet and Kutter considered that the Chezy formula, $v = c\sqrt{rs}$, was the correct point of departure, but that the coëfficient should be made variable, involving not only r and s, but likewise the degree of roughness in the bed or channel.

Ditches in California.—In the mining districts of California ditches are constructed boldly with steep grades and on irregular lines with numerous sharp curves. The cross sections, originally uniform, become more or less varied. Absorption, percolation, evaporation and leakage, reduce the flow. A distinct reliable factor for each of these sources of loss cannot well be incorporated in the coëfficient of discharge. If, then, it is intended to cover all of these common sources of loss by such

a coëfficient, its value must be a material modification of values given commonly in the text books. It would be certainly an affectation of accuracy to apply so complicated a formula as that of Kutter in such a case, since the modifying conditions which can be estimated but roughly, call for a large reduction of the calculated result. This will be apparent from the measurements of discharge given further on. The simple formula, $Q=ac\sqrt{rs}$, expresses more fitly the result of experience in such cases, wherein—

Q—Is the quantity of water which the ditch is capable of carrying in cubic feet per second?

a—The effective area of cross section of ditch as constructed originally, in square feet.

r—The hydraulic mean depth in feet.

s—The fall of surface in a unit of length.

c—A coëfficient covering all common losses.

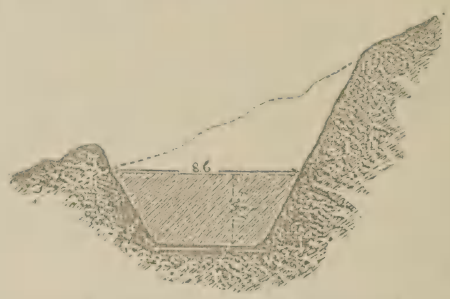

FIG. 2.—*North Bloomfield Main Ditch.*

Examples of value of Coëfficient in Ditches.—In its application to the North Bloomfield Main Ditch,* (length 40 miles, sectional area 23.89 square feet, grade 16 feet per mile) with its abrupt turns and sinuous course, the value of the coëfficient *c*, as determined, varies from 44.7 to 37.7 in accordance with the season of the year.

The Texas Creek† branch ditch is about seven-tenths of a

*Increase capacity of this ditch is limited by the pipes across Humbug Cañon.

†For details of Texas Creek ditch and flume, see paper by Hamilton Smith Jr., Transactions Am. Soc. C. E., Vol. XIII, pp. 30–31.

mile long. Its sectional area is 13.5 feet and the grade is 20 feet per mile. The sides are rough and the curves are sharp. With a flow of 32.8 cubic feet per second, the ditch runs about full. The value of c=33. In connection with this ditch there is a rectangular flume 2′.67 wide x 2′.83 deep, made of unplaned boards, set on a grade of 32 feet per mile. The flume has some sharp but regular curves, and the water from the ditch runs it nearly full at these points. With the discharge 32.8 cubic feet per second, c=59.

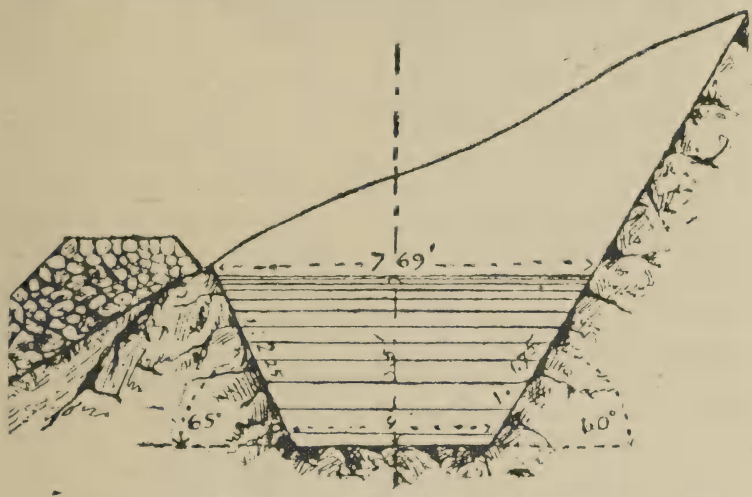

FIG. 3.—*Section of Milton Ditch.*

On the Milton line, from Milton to Eureka, a distance of 19.4 miles, the sectional area of the ditch is 20.39 square feet, grade 19.2 feet per mile for the earthwork and 32 feet per mile for flume. The line is very irregular, having many drops and chutes. The distance from Milton to the measuring box at Bloody Run is 29½ miles. The minimum established grade for the last 10.1 miles was 16 feet per mile, with a sectional area for the ditch of 23.05 square feet. The coëfficient c determined from the gauging at the measuring box has varied from 22 in its leakiest condition to 31, which latter can be taken as correct for the present condition. In the succeeding 30 miles below the

gauge, owing to a better character of ground, the coëfficient reaches 41.

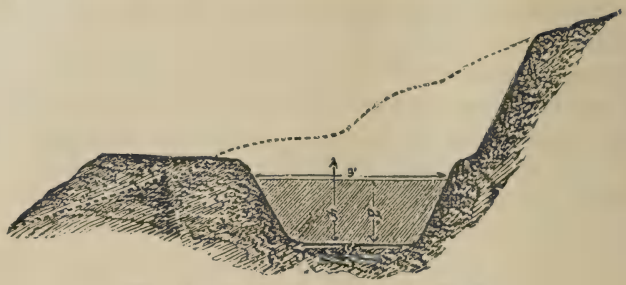

FIG. 4.—*Section of La Grange Ditch.*

The La Grange main ditch, 17 miles long, has a sectional area of 22.5 square feet, and a slope of 7 feet per mile. From the delivery at its Patricksville junction the coëfficient c is determined to be 52, but it is based upon the assumption that the depth of the canal is three feet, whereas in the original construction it was supposed to have been made four feet deep, the discharge therefore due to such a sectional area, would diminish necessarily the ascribed value of c*.

In all these canals, after the artificial banks are well consolidated, the water area is increased beyond the original excavation in the natural ground.

Accuracy cannot be expected in calculating the values of Q for proposed ditches of such character. Important losses must vary in every ditch, depending on the nature of the ground, and the character of the construction of the work and the season of the year. The feeders along the lines compensate largely for these losses. In order to be safe in estimating the capacity of a ditch, the value of the coëfficient c for the dry season should be taken.

The following facts show the magnitude of the losses due to absorption, leakage, evaporation, etc.:

Three thousand miners' inches of water (a flow of 75 cubic feet per second) turned in during the dry season at the head of the

*The grades given in all the above cases, from which the different values of C were calculated, exclude the drops, chutes, flumes, etc. Sectional areas represent minimum cross-sections.

Bloomfield ditch, will deliver 2700 inches (67.5 cubic feet per second) at the gauge 40 miles distant. Twenty-four hundred inches of water (60 cubic feet per second) turned in at the head of the Milton ditch delivered formerly at the gauge, 29½ miles distant, 1450 to 1600 inches (36.25 to 40 cubic feet per second), but at present 2500 inches (62.5 cubic feet per second) turned into the head of the ditch, delivers 2000 inches (50 cubic feet per second) at the gauge. The exact loss of water between the head of this ditch and the measuring box is shown in the following summary, taken from the official records for the month of August for the years 1875 to 1882, inclusive. This month is taken as a dry month, as prior to that time the numerous side streams swell the amount delivered at the gauge.

RECORD FOR AUGUST.

Year.	Water turned at Milton, 24 hours, inches.	Water record at Bloody Run, 24 hours, inches.	Per cent.
1875	44,000	34,950	79.4
1876	59,700	42,625	71.3
1877	67,875	44,700	65.9
1878	76,050	58,875	77.4
1879	82,725	51,350	62.0
1880	74,080	55,325	74.7
1881	66,850	48,325	72.3
1882	68,300	50,984	74.4

The Eureka Lake ditch, with 2500 inches turned in at the head, delivers at the gauge, thirty-three miles distant, about 1800 inches in the dry season.

The above statistics lead to the adoption of values of the coefficient c, varying from 31 to 45, in estimating the capacity of ditches on heavy grades of forty miles length flowing from sixty to eighty cubic feet per second, such as referred to—that is:

$$Q = 31 \text{ to } 45\ a\ \sqrt{rs}.$$

The loss incurred in the distribution of water is denoted by the following figures, taken from the official records of two mining companies. The amount received is measured, at or near the distributing reservoirs; the amount used, at or near the pres-

sure boxes. The difference shows the losses from leakage, evaporation, absorption, and wastage arising from excess of constant supply over the amount needed, with interruptions at the claim.

NORTH BLOOMFIELD COMPANY (24 HOUR INCHES).

Year.	Amount Received.	Amount Used.	Loss.
1870 to 1879, inc..	5,838,865	5,504,758	334,107 = 6 per cent.
1880..... ..	945,550	920,612	24,938 = 2½ "
1881*.....	950,340	866,962	83,378 = 9 "
1882.....	1,025,880	1,005,977	19,903 = 2 "
1883.....	862,660	836,251	26,409 = 3 "
14 years.....	9,623,295	9,134,560	488,735 = 5 per cent.

MILTON COMPANY (24 HOUR INCHES).

1882.....	685,933	635,884	50,049 = 7 per cent.
1883†.....	446,224	361,877	84,347 = 19 "
2 years.....	1,132,157	907,761	134,396 = 13 per cent.

*Much water run to waste during 4 months, owing to cessation of work caused by litigation.

†English reservoir was destroyed June 18, 1883, from which source the main water supply was obtained.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CABLE RAILWAY PROPULSION.

By W. W. HANSCOM, M. E., M. Tech. Soc.

Read June 6, 1884.

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MR. PRESIDENT AND GENTLEMEN—In presenting for your consideration a paper on Cable Railway Propulsion, I must premise my remarks by the statement that the subject is so comparatively new in its practical results, and so little has been done in the development of the system outside of San Francisco and Chicago, that we have but little of the experience of others which has been published upon which to rely for the collection of data. The subject matter of this paper will be mainly a collection of such facts and experiences as have come almost directly under my own observation, and such conclusions as I have arrived at are from the grouping together and endeavoring to find from these facts what constitutes some of the more important conditions connected with the construction and operation of cable railways.

The record which I have of the great number of persons who have directed their attention to this mode of propulsion of cars at once shows that the subject is not new, and that it has only waited until the particular time and conditions should arrive when it would be practically developed. This time arrived and the conditions were propitious, when the Clay Street Hill Cable Road was built, and from the time at which this experiment passed into the domain of practical and commercial success an increased interest has been manifested in the pecuniary results

to be attained, in comparison with the hauling of street cars by horses, and I need not enumerate the list of inventors whose patents have a bearing on this subject, and number several hundred, but pass directly to the features of the cable roads constructed and operated in our city.

In the construction of the Clay Street Hill Road, it was necessary to observe the strictest economy, as it was an experiment, or at least so considered by those interested, and consequently it was left to further experience to determine, in case of success, what should be the character and kind of material and workmanship to be adopted in the construction of additional cable roads.

In observing the condition of the street along which this road was to be constructed, it was found that it consisted almost entirely of grades, except at the crossings, which were level. These grades being in some places as steep as 1 in $6\frac{3}{10}$, and the steep grades made a sharp angle when leaving the level crossings, with curves of very small radius connecting the various changes from grade to level and from level to grade. The street was straight, so that there was only vertical and no lateral deflection. This was the serious matter, as in leaving a level crossing for a steep upward grade, the strain on the cable would bring it upward and through the slot of the tube made for the connecting bar between the car and the rope. Consequently it would require a sheave above the cable to keep it down at these points, so that while sheaves were used to support the cable when the weight and strain were downward, they were also required at certain points to counteract the upward strain, and whatever arrangement or apparatus might be used to correct the cable with the car, that part which clasped the cable must pass above the sheaves placed under the cable to support it and must also pass under the sheaves which were placed above the cable at points which were required to be kept down. These sheaves therefore must be at such distance apart, vertically, in reference to each other and the track (over which the wheels of the car which carried the gripping apparatus were to run) that when the car would be immediately over one of the sheaves which was under the cable, that the bottom parts which clasped the cable would be some little distance above the sheave, so that a slight

variation of the car or gripping apparatus in hight would not bring the grip and sheave in contact. Also when the car is directly over a sheave which is above the cable to keep it down, the top of the part which clasps the cable must be a sufficient distance below the sheave that it will not touch in passing. In order that these requirements may be met, the vertical part of the gripping apparatus which passes upward through the slot of the tube and connects with the car, must be so located that it will pass to one side of the sheave above the cable, and this is arranged by projecting the part which clasps the cable sideways from the vertical part, which is shown by the drawing.

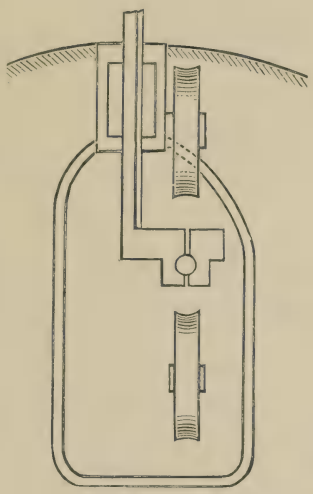

Fig. 1.

It will be seen that when the cable is held in the clasp, (or, as they are called, the jaws of the grip,) it is lifted above its normal position in the groove of the lower sheaves, and also that it is carried down away from the sheave, which is used to keep the cable down where sharp angles occur at upward change of grade.

This drawing shows the upward tendency of the cable in crossing a street and going up a grade; it being lifted from the lower or carrying sheave and brought up against the under side of the top or depression sheave.

This accedes to the conditions so far as a line is concerned, when there are no horizontal deflections occurring, and there are none on the Clay Street Hill Road.

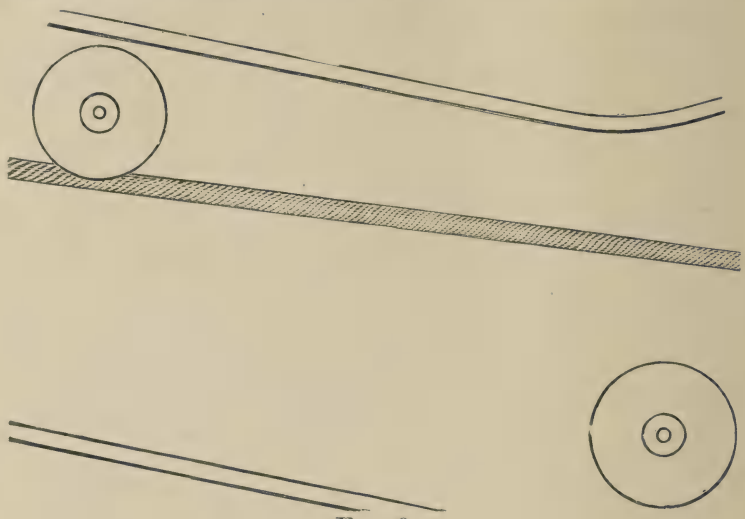

FIG. 2.

The form and size of the gripping arrangement being determined upon, such space between the lower and upper sheaves must be allowed that the grip will easily clear each, and some additional clearance space for variations which may occur in the hight of the grip by the wear of the wheels, or variations in the level of the track in reference to the tube, added. Then the diameter of the sheaves being fixed, this fixes the depth of the tube, and the width will be fixed by the width of the grip and sheaves and necessary clearance.

In constructing the Clay Street Road, wood was used to a large extent. Cast iron frames were made to conform to the desired cross-section of the tube, and placed about three feet apart, they having ribs cast on them so that planks two inches thick

could be laid from one to another, and held in position by the ribs, thus forming a tube of wood with supporting ribs of cast iron.

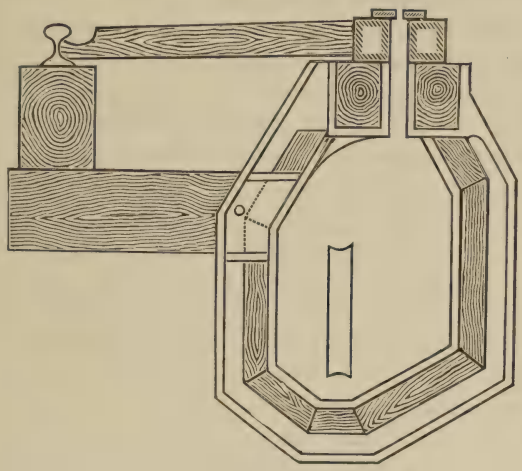

Fig. 3.

Ties extend laterally from these cast iron ribs, upon the outer ends of which are placed stringers which carry the rails. The castings, as shown, are open at the top, so that the vertical part of the grip may pass through, and close on each side of this opening, extending from one casting to another, are short car-lines, which are bolted at each end to the casting, thus keeping them at the proper distance apart and maintaining them in proper position. On top of these, and extending over several of the castings, are laid wood scantlings, which form the slot, and to protect the top from wear are placed iron straps fastened to the scantlings by wood screws. The surface of the roadway between the slots and the rails on each side is formed of wood plank, as shown. This forms the general construction of the tube from one end of the road to the other, except at the point where the cable is made to enter the engine house to be connected with the driving machinery.

Along the straight portions of the tube the lower sheaves are about nine inches in diameter; those above the cable being about

seven inches, as it was considered necessary to keep the distance between the surface of the street and the upper, enlarged part of the tube as small as consistent with strength to support the traffic of vehicles on the street, and also that the distance between the cable and the part of the car from which projects downward the vertical bar or shank (which has the grip on its lower end) shall be the minimum.

At the ends of the road are placed large sheaves, around which the cable passes to return, there being four tracks and two tubes, and the diameter of these large sheaves, which are placed with the axes vertical, is equal to the distance between the centers of the two tubes or sets of tracks, which is about eight feet. Experience in the use of wire cables had shown that where the cable makes any great change of direction, as a right angle or more, and even much less, the diameter of a sheave over which the cable passes should be about 100 times the diameter of the cable. In this road the cable was a little less than one inch in diameter, and the sheave about ninety-six inches. In order that the cars might be transferred from one track to the other at the end of the route, two turn-tables are arranged, the diameter of each being a little less than the distance between the centers of the two sets of tracks, each turn-table having two rails across it, equidistant from the center. These two tables are geared together, so that by turning one through an angle of ninety degrees the two sets of tracks will be brought in line with each other, and a car which had previously been brought from one of the lines of rails on to the table, can be pushed on to the other table, and then, by reversing the movement of the tables, the tracks are brought in line with the main line, and the car can then be moved on the opposite track, and on its return journey.

In transferring ordinary cars from one track to another, the tables would be simple plates placed on central pivots, and supporting rolls around the circumference; but the car which carries the griping apparatus and is called the dummy, having the shank of the grip projecting downward and through the slot into the tube, would in this case have to be raised out of the tube to allow the dummy to go on the turn-table. This operation would not only require time but the expenditure of considerable labor. That these might be avoided, the table was constructed of two

parts, an upper and lower plate connected together by ribs or ties. The top plate has a slot across its diameter, and the space between the upper and bottom plate will allow the lower portion of the grip to pass through—the ties between the two plates being far enough apart for the grip to pass through without touching. Now, as shown before, by revolving the tables one-quarter way round, the slots, through the upper surface of the plates, are brought in line with each other, and the dummy can, with its grip, be pushed from one table to the other, and so on to the other line of rails.

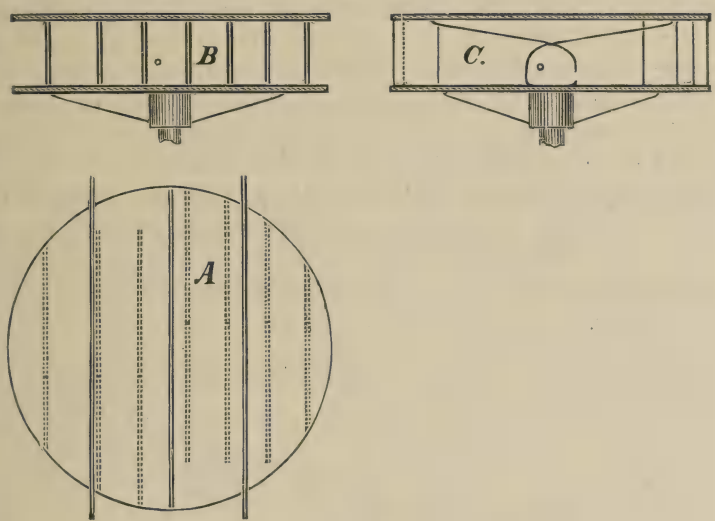

Fig. 4.

There is still one other requirement, and that is, that the cable shall also pass through the table, so that the dummy may be drawn on to the table and then dropped, and in order that this may be effected, the cable is carried through the table and some convenient distance beyond, before passing around the large sheave. Now the connection between the upper and lower plates of the turn-table must be so located that the table may be revolved through one-quarter of a circle without bringing this connection in contact with the cable, which is continually moving through.

A is a plan of the turn table.

B is a vertical section at a right angle to the slot which divides the top plate.

C is a vertical section in line with the slot through the top, and shows the manner in which the ties between the two plates are arranged so as to allow the cable to pass freely through when the table is turned so as to allow the car or dummy to pass from one table to the other.

As the large sheave at the end of the route lies in a horizontal position, or nearly so, a large pit or chamber is required, and the covering of this must be of sufficient strength to sustain any traffic which may pass over it, as it may be in the middle of the street; therefore, the thickness of this cover, and the fact that the axis or shaft of the sheave is vertical, it requires journal-bearings, both top and bottom, and this, added to the thickness of the cover, will carry the groove of the sheave some distance below the line of the cable in the tube, so that the cable at the point of leaving the tube to enter the chamber containing the large sheave will be deflected downward over a sheave somewhat larger than those supporting the cable in the tube, say 30 inches in diameter.

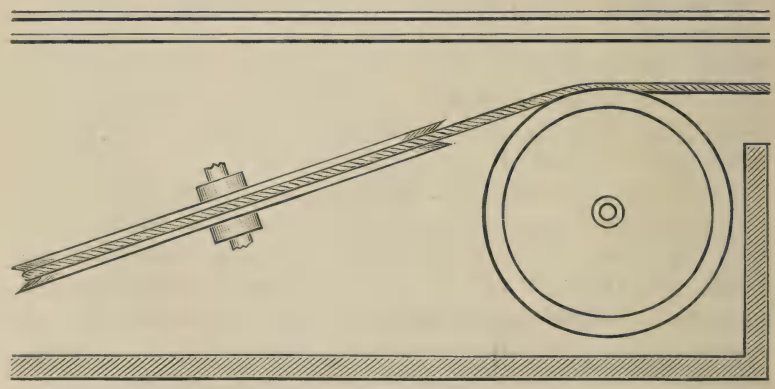

Fig. 5.

This large sheave is carried on a frame having wheels which run on a track prepared for it and of such a length that it may have a movement of 10 feet or more. A chain attached to the

end of this frame or carriage passes over a sheave at the rear end of the chamber and has a weight attached which maintains a tension on the cable passing around the large sheave, and will take up any stretch that may occur in the cable, and yet in case of excessive strain will yield and prevent rupture of the cable. A similar arrangement is at each end of the road.

At the point where the cable enters the engine-house the cable is deflected vertically over two sheaves eight feet in diameter, and thence at right angles to a horizontal direction, when they enter the engine-room, passing over a driving drum; thence over an idle sheave; thence over the driving drum again and backward to a sheave under the street, under which it passes and upward over a second sheave to the direction of and into the tube, when it continues on its route. These sheaves and driving drum are all eight feet in diameter. The driving drum is geared to the engine so that the cable has a speed of 528 feet per minute, or six miles per hour. There are 11,000 feet of cable employed in one piece, and it makes a total revolution over its route in about 21 minutes.

In changing the cars at the ends of the road the dummy is disconnected from the car and first transferred, then the car follows and is connected again to the dummy, and the train is ready to start so soon as the cable has been taken into the grip. This grip is so constructed that the cable is admitted between the jaws from the bottom side, and, as by opening the jaws the cable falls out, dropping away from the grip down into the carrying sheaves under the cable, it becomes necessary, in order to get the cable within the jaws again, either to raise the cable or to lower the jaws until they shall have brought the cable within them, and then raise the grip, bringing up the cable to such a hight that the bottom of the grip will sufficiently clear the sheaves. This grip is so constructed, that by a hollow screw at the top passing through a nut, which is supported by a frame and encircled by a hand wheel, the turning of the nut will lower the hollow screw, and with it the gripping jaws, until they are low enough to take the cable, when the jaws are partially closed, so that while they will prevent the cable from dropping down it will still freely pass through and not draw the train un-

til sufficient pressure is put upon it, which is done by means of a screw drawing a wedge between a frame and a bar, thus forcing the jaws against the cable with any desired force, the power by this arrangement being as 480 to 1; in other words, one pound applied to the screw by the man operating the grip gives a pressure of 480 pounds on the cable, less the friction of the moving parts.

That the cable may be spared abrasion in moving through the jaws of the grip when the dummy is standing still and the cable passing along, four rolls, having their circumferences grooved to suit the rope, are so arranged that they are a little in advance of the jaws and support the cable before the jaws come in contact with it. A spring is placed behind these rolls, so that they may yield when the jaws are brought together to grip the cable.

The cars are of such size that they will seat 14 persons, and weigh, unloaded, 2,800 pounds each; the dummies weigh 2,850 pounds each, and have seats upon them for 16 passengers.

As this road was extended after having been in operation about five years, some changes were made in the construction of the tube and in the cast-iron frame, which was extended laterally, so that it now comes under and supports the rails, and has its base extending the same distance, the web being perforated in the centre to the shape of the tube, and also openings between the central, and each side-ribs or flanges being formed all around the openings and the outside of the frame. The tube in the extension is formed of concrete, and as it passes through the openings of the frame it forms a monolithic structure the length of the road to which this mode of construction is applied. The slot is formed by channel irons six inches deep, with two-inch angles top and bottom bolted to the casting, and wood carlines are placed from frame to frame only to support the wood plank which forms the street surface between the rails.

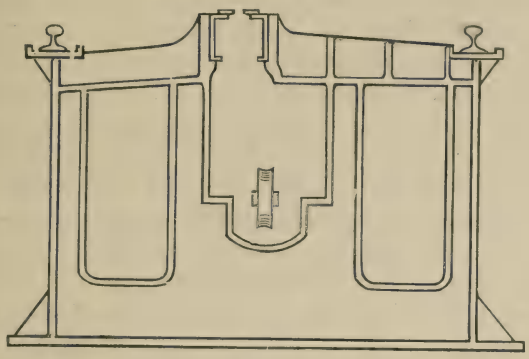

FIG. 6.

I have thus stated generally the most important features of construction in the Clay Street Hill Road, and in referring to the other roads will only allude to the more prominent conditions which involve changes in construction and operation, when they vary from the Clay Street Road. The next road to be operated by cable in this city was the Sutter Street Road, which had been operated by horses, but in 1876 was converted to a cable road. The more prominent change was in the construction of the gripping apparatus, which was arranged so that the jaws which take and hold the cable are moved vertically, so that the cable enters between the jaws of the grip from the side instead of from the bottom, as does the one in use by the Clay Street Road. These are distinguished from each other by the direction from which the cable enters the jaws. That of the Clay Street entering from the bottom is called a "bottom grip," and that of the Sutter Street entering from the side is called a "side-grip."

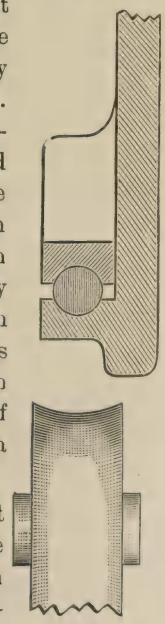

FIG. 7.

The side-grip is so constructed that it cannot be lowered like the Clay Street grip to take the cable, but has a fixed position when placed on the dummy. As the cable will normally lie directly under the jaws of the grip, either the jaws

or the cable must be moved sidewise to allow the cable to be brought up to a height which will allow it to enter the open jaws of the grip. As the readiest means of accomplishing the raising the cable, a sheave is so placed in the tube that the cable will be raised by it to a height corresponding to the opening of the jaws; but as without lateral movement of the grip it would strike the sheave, the rails and iron forming the slot are deflected, to carry the dummy and with it the grip to one side sufficiently to pass the sheave, and immediately again the track and slot is deflected into its normal direction, thereby bringing the opening of the jaws over the cable before the cable has sagged or dropped sufficiently to prevent it entering the grip.

In the later constructions of the grip, the points at which it is supported on the car are so arranged that it may vibrate from this point laterally, so that the dummy need not be carried bodily sidewise; therefore only the irons forming the slot are deflected. Wherever it is desired to let the rope out of the grip and take it up again the road is formed in this way, these points having been determined upon in advance.

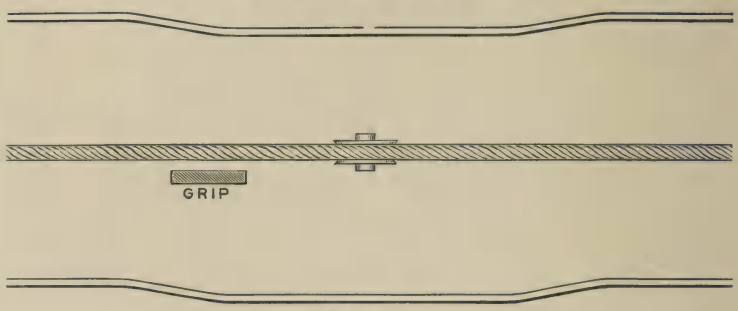

Fig. 8.

The plan for switching from one track to the other is different from that in use on Clay street. A tube is constructed leading across from one main tube to the other, and, following the curve of the rails which transfer the car and dummy from one main track to the other, the tubes are joined at the point of intersection. The slots of the tubes join similarly, and a tongue is placed at the junction of the two slots to cover the large opening into the tube at this point, and is also used to direct the shank of the grip into the proper slot.

These dummies and cars are not turned round in the operation of switching, as by the method by turn tables on Clay street, so that the cable lies on the same side of the tube, or rather the same side of the slot, in both of the main tubes. Of course, in switching or passing from one main tube to the other the rope is dropped from the grip, and as the dummy passes on to the main line the cable is brought up so that the grip may run on to it, as before described. At points where the car and dummy are transferred through a switch it is necessary to have a falling grade, so that, after dropping the cable, gravity may assist in carrying the dummy through the switch and on to the other main line. Where the street is officially level, latitude has been allowed the cable companies to make a grade to suit their desires.

At the point where the cables enter and leave the engine-house there is an intervening space between the two large sheaves which deflect the cable from and into the tube and engine-house. The cable is dropped from the grip just before reaching these sheaves, and a slight grade is given the street in the direction in which the car is moving, so that the car and dummy will start themselves or be carried over by gravity.

The driving drums are different from those in use on Clay street, where the drum has clips on its periphery in principle of action like Fowler's for driving wire ropes; while in Sutter street there are two single grooved drums in line with each other, one being slightly higher than the other.

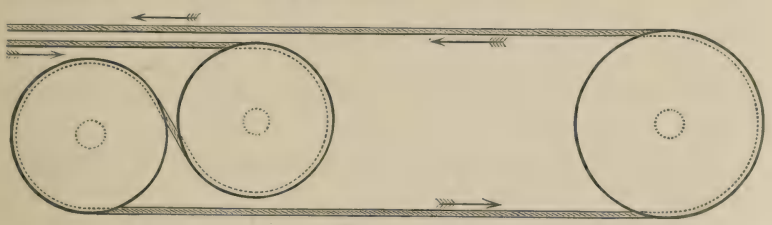

Fig. 9.

These are so placed that the cable coming in from the street will lead fairly on to the highest, which is in the rear, or farthest from the street. Passing around this, the cable is led forward and up, over, around and down under both of the drums form-

ing the figure eight nearly. Thence the cable goes backward and around a vertical sheave, which is carried by a carriage which can be moved on ways or rails provided for it. After passing around this latter sheave it goes forward again over the two driving sheaves or drums to the sheave in the street, by which it is again deflected into the tube.

The movable sheave around which the cable passes before reaching the street is arranged with a chain and weight, so that a definite amount of tension can be placed upon the cable, proportionate to its size and the work it has to do. This road has one other feature not in the Clay street road. That is, horizontal curves. The Larkin street cable passing a right angle from Polk into Post and from Post into Larkin and back again on the return track for deflecting the cable around these curves, which are from 40 to 50 feet radius; a series of horizontal pulleys, having no groove—but straight faces with a flange on the lower edge, are placed on the inner side of the curve about three feet apart, so that the deflection from one pulley to the next is slight. These pulleys are about 20 inches in diameter, and are set in iron cases which carry the bearings for the upper and lower journals of the upright spindles or shafts. The cable runs against the faces of these pulleys and they are set far enough to one side of the slot so that the grip in moving along would easily pass them; but to avoid positive contact between the grip and these pulleys, a bar of iron is placed around the curve, just above and a little in advance of the face of the pulleys, and, at a point on the shank of the grip, which would come opposite this bar, is placed a piece of iron called a wearing piece, which, being made smooth, comes in contact with and slides along the bar, thus keeping the jaws of the grip from contact with the pulleys.

The method of applying power to the grip used on this road is by a long lever, the short arm of which forms one part or joint of the knuckle or toggle lever, while the power is applied on the Clay street grip by means of a screw, or rather to a nut working on a screw, the nut being enclosed in and fastened to the hub of a hand wheel.

The construction of the tube for this road was originally similar to that first used on the Clay street, that is cast iron

frames and a tube of wood, but later the construction of the tube has been made by the use of wrought iron frames reaching to and supporting the rails, and making a skeleton tie for the rails, slot irons and tube, which latter is formed of concrete.

The California street road, which was the next one built after the Sutter street, is similar in its conditions to the Clay street, but having some steeper grades, and as it was intended for heavier traffic a larger cable was used, being one and one-quarter inches in diameter.

The tube is constructed of a frame of wrought-iron, reaching out and supporting the rails, which was copied in the later construction of portions of the Sutter street road above alluded to. In the case of the California street road, however, the main element of the wrought-iron works was made of old rails.

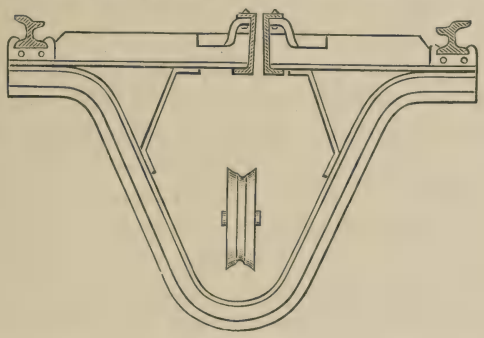

Fig. 10.

At the location of the engine house, ground area being limited, the driving drums for the cable were placed under the street, one under and in line with the center of each track. The drums are the same as those used on Sutter street. Tension sheaves are used, the cable passing over them both before going onto the driving drums and after leaving them, and before passing into the tube. The action of these tension sheaves was by gravity, but instead of having a weight attached to the movable carriage which carries the sheave, the track on which the carriage runs in this case is on an incline, so that gravity acts directly upon the carriage and sheave. The carriage is so constructed that weight may be added as desired in a boxed part.

Switches are used at the termini for transferring cars and dummies from one track to another, a tube being used for the grip to pass through the same as on the Sutter street road. The grip used is the same as on Sutter street, that is a "side" grip.

The Geary street road is similar in general conditions to the Sutter street, except that it has no curves, the road being straight from end to end, and the angles at the changes of grade are so slight that no depression sheaves are used to keep the cable down.

The grip used on this road is a "bottom" grip, but is operated by a lever applying the principle of the toggle joint.

The cars are transferred at one end of the road by a switch like Sutter and California streets, but at the other by a turn-table. The turn-table being of a diameter sufficient to hold one car is placed with its center of revolution in a line with the center of the out-going track. The incoming track is curved, and the straight portion running onto the turn-table forms an angle with the out-going track of about 30 degrees. This economizes space, and dispenses with the second table as used on Clay street. The driving drums in use on this road for moving the cable are different from any other road, there being two, and each having several concentric grooves so that the cable is passed around the two drums until a sufficient number of wraps are made to prevent slip. In this case, no tension sheaves are used to give adhesions to the cable around the drum. Four or five wraps of the cable are all that is necessary. The tension sheaves, for taking up the stretch and slack of the cable are on movable carriages, and are drawn backward by a long screw.

The Union street or Presidio and Ferries road has the steepest grades of any road in the city, and has one horizontal curve, where the line passes from Montgomery Avenue to Union street. In this case, the cables are led away from the curve of the track, passing around large horizontal sheaves to change the direction of the cable from one street to the other, and the grades at the curve have been so modified, that the cable having been let out of the grip, the train passes the curve by its momentum, assisted somewhat by gravity.

The driving drums are the same as used on Clay street; also the grip.

The transferring of cars and dummies at the termini are by switches, turn-tables being used only at the engine house for turning the cars on and off the road.

The Market street road, the latest built, has some features different from all others. The construction of the entire railroad bed is the same as California street, except in the form of iron work of the frame for the latter, which is of the same kind of materials as are used on California street. The cars carry the grip instead of having a dummy, as on all the other roads.

The driving drums are the same as are used on California and Sutter street roads. At the junction of Market with Haight and also at McAllister streets the Market street cable is dropped, and the cable running in Haight and McAllister streets is picked up, as the car is carried by its momentum around the curves into either of these streets, assisted by gravity due to a grade modified for the purpose. At the curve on Market and Valencia streets an auxilliary cable is used for bringing the cars past the engine house. This cable is used only on one track coming east, the cars going west having to drop the cable and are carried around the curve by gravity. The speed of this cable is one-half that of the main cables and it is driven by a grooved pulley or sheave on the line shaft which carries all the other driving drums.

The cables on Market, Valencia and Haight streets are driven by the same engine, while a separate engine is used for operating the McAllister street cable. At Haight street, the curve from Market street is passed the same as on the Union street road at Montgomery avenue and Union street, but at the junction of McAllister and Market after dropping the Market street cable, the McAllister street cable is picked up before reaching the curve, and the grip holds the cable while passing it, the horizontal pulleys around which the cable passes being arranged similarly to those heretofore referred to at the corner of Post and Polk, and Post and Larkin streets on the Sutter street roads.

At the termini of these roads, the Market, Valencia, Haight and McAllister streets, which comprise the Market Street Company roads, the cars are transferred from one track to the other by a turn-table somewhat similar to that used at one end of the Geary street road, with this difference: On Geary street the

dummy or car is not turned around, but either end runs foremost, so that in changing the turn-table from the incoming to the outgoing track the table is moved through only thirty degrees.

On the Market street cars the grip is placed on the truck at one end of the cars so that the car requires to be turned half way round at each end of the route. The table in this case has to be moved through 180 degrees, and there are two parallel tracks across this turn-table, each equidistant from the center, the distance between the centers of the tracks being equal to the distance between the centers of the main tracks, so that when the table has been moved so that a car is in position to go off, the other track on the table is in position to receive a car from the incoming main line. As these turn-tables are large and heavy they are turned by gearing driven by the main cable, through a grooved pulley, which being connected with the gearing is brought against the cable with sufficient pressure to give the desired power. The cables used by this company are the size of the ones used on California street (1¼ inch in diameter).

On McAllister street where the road crosses to Fulton street, there are four curves of about 45 degrees each, with the horizontal pulleys arranged similarly to those on Post, Polk and Larkin streets of the Sutter street road.

These facts concerning the general features of the various roads are incidental to important questions, that of the economy in construction, maintenance and operation of the cable system of propulsion for street cars.

In order to direct an intelligent inquiry into the subject, I have divided it into three general heads:

1st.—Construction.
2d.—Maintenance.
3d.—Operation.

Each of these divisions, of course, have many details, but for the purpose of this paper I have made them somewhat general.

Under the head of Construction, I have placed the construction of:

1st.—Road-bed and tube.
2d.—Driving machinery.
3d.—Gripping apparatus and cable.
4th.—Cars.

Under the division of maintenance I have placed:

1st.—Road-bed and tube.
2d.—Driving machinery.
3d—Gripping apparatus and cable.

Under the division of operation, I have placed:

1st.—Power for driving the cable.
2d.—Power for driving the cars.
3d.—Power for hauling passengers.

In the construction of the road-bed and tube, it will be noticed that we have advanced from the first experiment of wood and iron to concrete and iron, with stone paving for the surface of the street and with steel for rails. Probably we have gone to the extremes in this respect as far as cost is concerned, for we have constructed the tube and the road-bed of the most lasting materials, with all the strength to support the heaviest traffic which will ever be allowed over the streets of any city, the surface being composed of materials which are best known, by experience and judgment, to resist the wear to which they may be exposed; and these materials have been used in a generous manner. The increase in economy will consist in the reduction of material to the minimum required to meet local conditions, and an exercise of careful judgment in the manner and distribution of labor in the combining and placing in position the materials of construction. The apparent cost of similar forms of construction of the road-beds and tubes of the cable roads in this city vary so much that it would be delusive to base estimates of the cost of a projected road upon the generally reported statements concerning the cost of those already built. The conditions to be observed for the street surface are that the grades of the street shall not be disturbed, or that no protuberances or depressions shall be made to interfere with traffic of teams or vehicles, and that the strength of the tube shall be sufficient to easily support

the heaviest weight which may ordinarily come upon it without disturbing its shape.

In the construction of the driving machinery, some basis for consideration may be had by a comparison of the weights of the moving machinery for the roads in this city, when they are each compared with the weight of the cables which they propel and support. It may be taken for granted that the weight of supports and foundations for the moving machinery will be proportionate to the weight they have to carry.

The weights of moving machinery include the moving parts of the engines, shafts, fly wheels, pulleys, sheaves and gears, in the engine house; also, the deflecting sheaves, which change the direction of the moving cable, and the carrier sheaves, which support the cable in the tube along the street.

The approximate weights of moving machinery and cables on the various roads of San Francisco are as follows:

Name of Road.	Weight of Machinery, pounds.	Weight of Cable, pounds.
Clay	22,000	15,400
California	100,000	65,000
Sutter	240,000	68,000
Geary	60,000	37,800
Union	80,000	30,500
Market, Valencia and Haight	240,000	164,412
McAllister	100,000	68,000

To compare the weight of moving machinery with the weight of cable, let the weight of cable be 1, then the weight of moving machinery will show as follows:

Name of Road.	Weight of Rope. =1.	W't of Machinery
Clay	1	1.428
Market, Valencia and Haight	1	1.459
McAllister	1	1.47
California	1	1.538
Geary	1	1.587
Union	1	2.622
Sutter	1	3.529

These figures are somewhat suggestive. As the cost of machinery of this character is generally sold in the market by the pound, it is comparatively easy to estimate the cost of the driving machinery, and as the cost will be generally in proportion to the weight, due consideration should be given to this division of the construction account.

In the construction of the gripping apparatus there are several considerations which have much influence on the cost: First, is the work which they are required to do; second, the conditions under which this work has to be performed; and third, the promptness with which they can be manipulated. In referring to the first condition, the work which the grip has to perform depends to a large extent on the grades over which they have to act. Allowing 20 pounds per ton for the friction of cars, then a grade of one in one hundred, or one per cent., doubles the strain on the grip. The steepest grade on the roads of this city requires as much power to be developed by the engine in hauling one train over it as would be required to haul eighteen trains on a level.

While the amount of work put on the grip calls for strength and power, the requirements of passengers and care for human life necessitate a construction which will admit of prompt action, and this is a very important feature in their construction.

There may be conditions existing under which it would be greater economy for the grip to break than to withstand the strain to which it is liable to be exposed, but as a general proposition it is a fallacy to assume anything of the kind. It is a condition of things which should not occur, and will not, with competent engineering ability.

The first consideration is to construct the grip to meet the actual requirements as to work, promptness, ordinary wear and convenience in handling.

In the construction of the cable much has yet to be learned. The principal condition is that it shall be sufficiently strong, after considerable wear, to withstand probable extraordinary strains; at the same time it shall not be unduly large, which adds to the weight and cost. Having an exterior surface, which is hard, so as to withstand the abrasion of the jaws of the grip, yet the

flexibility of the cable shall be of such a degree that it will easily bend in passing over the sheaves and drums which change its direction.

The greater the diameter of the cable the more friction and abrasion, and power required to bend it around the sheaves which it passes. Various kinds of cables have been used on these roads—both of iron and steel, and large and small—and with various degrees of hardness. So far, the crucible steel cable has been adopted in preference to any other, possessing hardness and strength, with flexibility. It is probable that changes in the lay or twist of the strands in making may effect an improvement in working.

In the construction of cars there is at present but little difference, in general views. Whether a dummy and car should be used together, or each car have a grip attached to it, is a question which will be answered differently by different local conditions, a prominent condition being all intelligent provisions for the safety of passengers in boarding and alighting from. As the larger part of accidents on these roads occur by the negligence of the injured, all means consistent with convenient access to and departure from the cars and dummies should be provided to prevent accidents.

In the maintenance of road-bed and tube, the present method of uniting concrete and iron leaves not much to be desired, the rails and the paving being the only parts that require renewals during many years. The rails and slot irons should be so put down that they may be taken up and renewed without detriment to the tube or unnecessary disturbance of the materials of which the tube is constructed.

Concerning driving gear and the moving machinery connected with the cable, the engines which may be used are so well known that any style, kind, or power may be obtained to meet any condition which would arise under local circumstances. In the various arrangements for carrying and deflecting the cables we have some differences in detail, but in plan all are similar. This is a matter that has not received the consideration that its importance demands. As a large portion of the power expended is exhausted in wearing out the driving machinery and carrying

and deflecting sheaves, these should have careful study that they may do the work assigned them with the greatest economy of wear and friction.

The first table shows the comparative weights of driving and carrying machinery and the cables which they carry. For the maintenance the cost may not always be in proportion to the weight, but the more weighty it is made the more is the wear and the more attendance and lubrication is required, as well as the increased cost of construction.

The third division under maintenance is the gripping apparatus and cables. These are mutually dependent one on the other. In the grip the wear comes on the jaws which clasp the cable, and these are now made removable, so that they can be made of the least possible weight and easily renewed, they being composed of soft cast-iron, that having with the experience so far proved the most economical of any material yet used. As the contact or connection between the grip and rope is entirely one of friction, it becomes a question of how great an abrasion or wear of the jaws of the grip can be allowed in saving the wear of the cable without costing more than the wear of the latter. When cables are newly laid they cause a much more rapid wear of the jaws of the grip than after they have been in use some time. The cause is that when new the exterior wires composing the cable are comparatively sharp cutting edges, but they are gradually worn down or flattened by the action of the grip jaws upon them, and, in addition, a coating of tar is put on the cable, which fills up the interstices, and by frequent applications the surface of the cable becomes so smooth as to resemble a bar of iron in passing rapidly along. This condition reduces the wear of the jaws and their life is increased from 200 to 400 per cent., and even more. There are two advantages in this filling of the cable with tar, one of which is to lubricate the cable to a certain extent, so that when taking hold to start a train the slip of the cable through the grip causes the train to start more gently and at the same time the wear on both grip jaws and cable. The tar alone on the cable would not effect this purpose, but by the addition of a small quantity of oil the surface of the tar is prevented from adhering to the grip or to the sheaves over which it

passes. The maintenance of the cable is one of the great expenses in the operation of cable roads, or rather it has been, from several causes, first of which is the excessive wear or action upon it by the jaws of the grip, especially when a road is first built and new men have to learn the road and get experience in the handling of the grip in starting and stopping. Whatever kind of cable may be used the abrasion may be increased very largely by this action of the grip, and the experience with cables in this city has demonstrated that the life of a cable may be doubled nearly by the manner of applying the grip to the rope.

Another cause is the construction of the grip for relieving the cable from frictional contact when the car or train is standing still and the cable allowed to pass through the grip. The grips are usually so constructed that the cable is supported and guided by grooved rolls when the jaws are loosened, the rolls keeping the cable from coming in contact with the jaws. Some of them, those called "side" grips, support the cable by rolls under the cable, the jaws having a vertical movement.

The rolls being stationary, so far as vertical movement is concerned, when it is desired to start the car, the upper jaw is forced downward on to the lower jaw. In one grip in use in this city, the upper jaw extends over the friction rolls, so that the cable is forced against the rolls, and the lower jaw being shorter than the upper in this case, the lower jaw has to be at such a hight that the cable will be compressed between it and the upper jaw as well as between the upper jaw and the friction rolls, so that the cable must lie partially on the lower jaw, whether compressed or when moving freely through the grip. Another grip, the rolls are placed so far apart that both upper and lower jaws are considerably shorter than the distance between the friction rolls, and the upper jaw in being forced down on to the lower jaw, carries the cable with it, and when raised, the cable travels entirely on the rolls, being free from the lower jaw. In the grip in use on the Geary street road, the grip opens at the bottom, and not having any friction rolls, the cable lies and moves on the jaws of the grip when the cars are standing still. On roads where frequent stops are made, the wear of the cable increases. Other things being equal, the wear of the cable will be in proportion to the number of stops made, and its life inversely.

So far, the greatest factor in the destruction of the cable is the grip, and experience shows that skill in operating it adds to the life, and consequently economy of maintenance of the cable. The length of the jaw, which embraces the cable, is not known yet to affect the life much, but it seems that a jaw having a length of 8 to 10 diameters of the cable, is sufficient to prevent any pressure from bruising the cable, and yet will hold any load that has yet been taken up the steepest grades in this city. The practical requirements for economy of maintenance of cable, are that the grip shall be so constructed that friction rolls shall support the cable free from the jaws when it is passing through them, and the frictional contact shall be between the jaws entirely when propelling a car; that the operator of the grip shall be a man of intelligence, who can apply the grip to start the car quietly, and have the least amount of slip of the cable through the jaws. It does not follow that the one who starts the car the easiest or most gently, will wear out the jaws the soonest. Experience has proved the contrary. Lastly, continuous care of the cable, in keeping it well filled with tar and properly oiled.

Under the head of operation, I have placed the power required to propel—1st, the cable; 2d, the cars; and 3d, the passengers. In order that a comparison may be made, I have taken indicator diagrams from the roads in San Francisco, and the table herewith shows the amount required for driving the cable alone—I mean by this, without any cars being on the road; but included is the friction of the engines and driving machinery; also the friction of the carrying and deflecting sheaves, as well as the power consumed in bending the cable around the sheaves. I have not attempted to segregate the power required for driving the cable from that required to move the engines and driving machinery without the cable on, because all this power is in constant use, is a constant expense, and the fuel expense for driving a certain amount of cable at a certain speed, depends upon the ability of the constructing engineer to design, and a proper direction of the labor having the care of it when in operation. For the purposes of this paper, I have reduced the work done on the various roads, to the number of pounds of cable moved one mile per hour with one horse power.

Name of Road.	Horse power to drive cable.	Pounds of cable moved 1 mile per hour with 1 horse power	Proportionate power required for driving cable, Clay St. being 1.
Clay	22.6	4,084	1.00
Sutter, estimate	83.6	4,538	.90
Geary, estimate	58.0	4,538	.90
California	84.0	4,743	.861
Union	39.0	4,788	.852
Market	201.0	6,221	.656
McAllister	60.0	9,066	.45

In this table the power for moving the cables of the Sutter Street and Geary are estimated by taking the average of the work done on the Clay, California and Union Street roads.

For the power to haul the cars I have allowed 20 pounds per ton at all speeds. This would give for the various roads an approximate power for each train, consisting of dummy and car, and on Market and McAllister, for the car alone:

Name of Road.	W't of Car & Dummy.	Horse Power for ea. Car.	Average No. of Cars.	Total Aver'ge Power for Cars.
Clay	4,900	.08	7	5.60
Sutter	7,500	1.50	18	27.00
California	8,600	1.40	14	19.60
Geary	8,400	1.94	19	36.86
Union	8,600	1.42	10	14.20
Market and Haight	9,600	2.07	44	91.00
McAllister	9,600	2.07	18	37.00

The following table gives the approximate average speed of each road, the average distance that passengers are carried, the total number running hours each day, and the average horse power required to haul 1,000 passengers on each road:

Name of Road.	Average speed.	Average distance that passengers are carried. Miles.	Total hours running time each day.	Average power for each 1000 passengers carried. Horse Power.
Clay.....	6	$\frac{1}{2}$	$17\frac{1}{2}$	.0971
Sutter.....	$7\frac{1}{2}$	$1\frac{1}{2}$	$19\frac{1}{2}$	.261
California.	6	1	19	.178
Geary.....	$7\frac{3}{4}$	1	19	.177
Union.....	6	1	$17\frac{1}{2}$	.194
Market.....	8	$2\frac{1}{2}$	$20\frac{2}{3}$	.412
McAllister...	8	1	$20\frac{2}{3}$	.163

This table shows that the power required to convey passengers by themselves is a small factor of the total power required in operating cable roads. It is assumed here that the average distance which each passenger is carried will be about half the length of the road.

The following table will give the total daily average power for operating the cable roads in this city, and also the per cent. of power required for moving cable, for moving cars, and (assuming numbers) for moving passengers:

Name of Road.	Total Power	For Cable.		For Cars.		For Passeng's		Number of Passengers.
		Power	Per ct.	Power	Per ct.	Power	Per ct.	
Clay.....	28.56	22.6	79.0	5.60	19.0	.36	2.0	4,000
Sutter (estimated)	114.60	83.6	72.9	27.00	23.5	4.00	3.6	15,000
California.....	105.02	84.0	80.0	19.60	18.6	1.42	1.4	8,000
Geary.....	96.63	58.0	60.0	36.86	38.0	1.77	2.0	10,000
Union.....	54.55	39.0	70.0	14.20	26.0	1.35	4.0	7,000
Market.....	301.00	201.0	66.7	91.00	30.6	9.06	2.7	22,000
McAllister.....	98.30	60.0	61.0	37.00	37.6	1.30	1.4	8,000
	798.66	548.2	68.0	231.26	28.0	19.26	4.0	74,000

These results are the average percentages for estimated average number of cars and passengers. The following table gives the average number of feet of cable for each car, except Market

Street, to which should be added the cars which are switched from the McAllister Street road:

Name of Road.	Number of Cars.	Feet of Cable.	Feet of Cable to each Car.
Clay	7	11,000	1,571
Sutter	18	37,736	2,096
California	14	25,895	1,844
Geary	19	27,000	1,421
Union	10	21,000	2,100
Market	44	65,765	1,472
McAllister	18	27,183	1,510
	130	215,579	12,014
Average	18.5	30,797	1,716

This table shows the average distance apart of cars to be 1,716 feet for average running, but on holidays and Sundays these distances have been reduced about 45 per cent., so that cars have run 1,000 feet apart, average. I am aware that in some instances they have run much less distance than this, but at eight miles per hour the speed would be 704 feet per minute, or an interval of about $1\frac{1}{2}$ minute between cars, allowing for stops. Of course, if traffic demanded it, this number of cars could be kept on the road. That would be one car to each 1,000 feet of rope, and taking the totals from table above, there would be added 85 cars; and if each car carried the average number of passengers, they would be increased 48,000, or 65 per cent., so that 65 per cent. would be added to the power required for hauling the cars, which would be 231.26+150.31=381.57 for cars, and 65 per cent. for passengers would be 19.26+12.51=31.77 horse power. Then the total power would be—

For cables	548 2
For cars	381.57
For passengers	31.77
	961 56

Of which 57 per cent would be for cable.
39 " " " " " cars.
and 4 " " " " " passengers.
100

This is taking the average of all the roads, but if we take the road which has the least per cent. of power expended in moving the cable, the Geary Street, and add cars so that they may be only 1,000 feet apart, we shall have 8 more cars—an increase of 42 per cent. and also an increase of 42 in the total power for hauling cars and passengers, thus:

For moving cable	58.	H. P.
For moving cars	52.34	"
For moving passengers	2.84	"
Total H. P.	113.18	

Of which 51 per cent. would be for moving cable.
46 " " " " " " cars.
and 3 " " " " " " passengers.
100

This is within the capacity of the road as it in this case assumed, carried 14,200 passengers; while it has actually many times carried from 20,000 to 22,000 passengers in one day.

Therefore we may conclude that it is practicable to utilize 50 per cent. of the total power expended in moving the cars and passengers. That this is much within bounds will be admitted when it is seen that the comparative power expended in moving the Geary Street cable is .90, and that of McAllister Street is only .45, or one half.

There is one other point which I will refer to, and that is the comparative power required over grades or level roads. While the average will remain about the same, the fluctuations will be much greater and the consequent maximum strain on the cable will be greater over grades, and this variation of work calls for an engine that will keep a uniform speed under more severe conditions than usually obtain even in rolling mills, for if the speed of the engine in the mills varies somewhat human comfort is not affected by it; but in cars moved by cable, any variation in the speed of the engine may be easily detected by the surging movement which is given to the car. There is no difficulty in providing engines that will run at a uniform speed under all the changes or variation of work that may come upon it.

There are other points of importance which might be referred to in this paper, but it has already extended beyond the primary intention. Our future experience will be guided and aided by the past, and the divisions of the subjects which are but little understood at present, will become as familiar as household words.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

REGULAR MEETING.

June 6, 1884.

Vice-President Specht in the Chair.

The following propositions for membership were read:

L. L. Robinson, proposed by Messrs. Mendell, Specht and Bowie.

Sanford Robinson, proposed by Messrs. Mendell, Specht and Bowie.

A. J. McNicoll, proposed by Messrs. Percy, d'Erlach and Pierce.

Jno. D. Hoffmann, proposed by Messrs. Allandt, Von Leicht and Pierce.

Seth Balson, proposed by Messrs. Percy, Wagoner and Schuyler.

P. H. Jackson, proposed by Messrs. Percy, Yale and Dickie.

A paper ("On Cable Railway Propulsion") was read by W. W. Hanscom.

A paper ("On the Measurement and Flow of Water in Ditches") was read by Aug. J. Bowie, Jr.

[These papers were published in the pamphlet of the Society, which was issued in June.—SECRETARY.]

Mr. Bowers submitted two amendments to the by-laws, to be acted on at the subsequent meeting.

The Chairman announced the death of Mr. Edward Yorke, and the Secretary read a letter from Wm. Ham Hall, giving an account of Mr. Yorke's death.

On motion of Mr. Manson, a committee was appointed to draft resolutions. The Chairman appointed Messrs. Manson, Hall and Schuyler.

REGULAR MEETING.

July 11, 1884.

Vice-President Specht in the Chair.

The following members were duly elected:

L. L. Robinson, Sanford Robinson, A. J. McNicoll, J. D. Hoffmann, Seth Babson and P. H. Jackson.

The following propositions for membership were made:

Irving Stringham, proposed by Messrs. Wheeler, Browne and Wagoner.

Constantius Heusch, proposed by Messrs. Specht, Hoffmann and Von Leicht.

A. H. Payson, proposed by Messrs. Mendell, Roessler and Smith.

L. J. Le Conte, proposed by Messrs. Mendell, Smith and Roessler.

A paper "On the Retorting of Gold and Silver in Vacuo," was read by Fr. Gutzkow.

A paper entitled "A Criticism of Becker's Theory of Faulting," was read by title by Ross E. Browne.

A paper "On the Treatment of Torrential Sediment-Bearing Streams in Europe, and its Application to California," was read by George J. Specht.

The report of the committee appointed to draft resolutions in respect to the memory of the late Edward Yorke, a member of the Society, was read as follows:

WHEREAS, Through the working of an unknowable Providence, our brother, Edward Yorke, has been suddenly taken from this life, and since he was well and intimately known to many of our number—

Resolved, Therefore, that we realize in the death of Mr. Yorke, the loss of a man whose accomplishments and experience fitted him for a useful and desirable member of our young society; and that in time, the members will miss one whose personal qualities made his conversation instructive, and his companionship agreeable;

And Whereas, These qualities were such as must have endeared him to those to whom his fortune was linked by family ties—and especially so to a wife.

Resolved, Therefore, that we are moved by a deep sympathy for those thus sadly bereaved, and particularly her who is widowed by his death; and that we extend to them all the consolation which mourning friends can hold forth.

Wm. Ham Hall,
Jas. D. Schuyler,
Marsden Manson,
Committee.

The following amendment to Article I of the By-Laws, introduced by Mr. Bowers, was adopted:

"Meetings for social intercourse, discussion of papers read at the previous monthly meeting, reading of correspondence and discussion of subjects relating to the theory and practice of technical science, shall be held on the last Friday of each month, and no other business shall be transacted at said meeting."

The following amendment to Section 1, Article V, of the By-Laws, proposed by Mr. A. B. Bowers, was adopted:

"The President of the Society shall be an Honorary Member of all committees."

REGULAR MEETING.

August 10th, 1884.

Col. Geo. H. Mendell, President, in the Chair.

The following members were elected:

Louis A. Sengteller, John W. Ferris, Constantius Heusch, Irving Stringham, A. H. Payson, L. J. Le Conte.

Propositions for membership:

Victor U. Clement, proposed by Messrs. Wagoner, Wheeler and Manson.

M. C. Lauton, proposed by Messrs. Bowers, Mendell and Manson.

P. J. Flynn, proposed by Messrs. Mendell, Smith and Specht.

E. A. Rix, proposed by Messrs. Yale, Ransome and Specht.

Mr. P. H. Jackson read a paper (from a forthcoming work) on "Concrete and Iron Construction."

Mr. Percy described the process and results of some experiments with combined iron and cement for sidewalks, etc.

On motion of Mr. Specht, the following resolution was adopted:

That the Chair appoint a committee of five to take means to investigate and report the necessary steps to establish a unit for the measurement of water, said committee to report in September.

The Chair afterwards appointed as said committee, George J. Specht, Aug. J. Bowie, Jr., W. R. Eckart, G. F. Allardt, and Ross E. Browne.

NOTE.—The delay in the publication of this number of Volume I of the Transactions of the Society has been occasioned by the destruction by fire of the plates designed to accompany Mr. Specht's paper. On the day the plates were completed, the lithographic establishment where the work was being done, was burned—the plates and original drawings referred to being destroyed with the other material. This necessitated the work being done over again. The "papers" were all in type, but nothing could be done toward printing them until new engravings were completed.—SECRETARY T. S. of P. C.

DISCUSSION OF MR. HALL'S PAPER ON THE SEWAGE QUESTION IN CALIFORNIA.

[Mr. Hall's paper was read May 2, 1884, and was published on pages 25 *et seq.* in the Transactions of the Society, Vol. I, No. 1.]

Mr. A. B. Bowers—The subjects presented by Mr. Hall are numerous and important, but he treats and professes to treat them only in general terms. He specifies certain substances (not usually so classified) which he groups under the general term of "sewage matter;" points out some deleterious results arising from an improper disposal of these substances; and enumerates some of the principal systems, theories and processes for their disposal now undergoing the test of practical application, passing without notice some of the more recent and best. He also presents certain conclusions to which he has arrived; certain views as to their local application; and certain predictions concerning future practice in this State, regarding some of which there must be diversity of opinion.

Some years since I was led to examine the means and cost of excavating and transporting mud. My experiments proved that with suitable apparatus this work can be done at a much less cost than is usually paid and much less than most engineers will admit to be possible.* Now, dock mud, in many cases, largely consists of sedimentary deposits from sewers, and supposing this deposit to possess a high manurial value, I was naturally led to a re-examination of sewerage irrigation, the construction of pumps, sewers and

*With a small experimental machine, costing about $12,000, of less than 50 indicated H P., I put an average of 6½ cubic yards per minute of stiff clay on shore through 320 feet of pipe. See report of G. L. PIERCE, M. E., Mem. Tech. Soc., etc., with accompanying certificates.

sewerage works, and, incidentally, of house drainage, plumbing, pavement of streets, construction of silt basins, under drainage, and a wide field of sanitary engineering relating to these subjects. I could, therefore, speak with some confidence on all questions presented by Mr. Hall, did not the state of my health and instructions of my physician limit me to a brief notice of only a few of them.

In the construction of sewers and drainage of towns the engineer stands on solid ground. The experience of many engineers, successful and otherwise, furnishes him a safe guide, and he need resort to no doubtful expedients, though here, as in other important undertakings, good judgment is essential to success. He is confronted at the outset with the question of a double or single system, whether to mix the rainfall and surface drainage with the sewerage in whole, in part, or to keep them entirely separate.

If the sewerage must be pumped, its solids precipitated, and liquids clarified preparatory to the discharge of these liquids into a watercourse that must be kept as free as possible from contamination, the rainfall and surface drainage should be excluded from the sewerage, either wholly or in part, to reduce the cost of pumping. The sewers should be much smaller than would otherwise be necessary, though small pipes require a higher grade than large ones. House drains should enter the sewers obliquely, to accelerate rather than retard the flow. All joints should be perfectly tight; all connections with house drains laid in cement, to prevent the escape of foul liquids and contamination of street and cellar and basement; to prevent also the infiltration of subsoil water, and keep down the cost of pumping and precipitation. The house drain, as well as every sink, basin, or other connection with said drain, should be securely trapped to prevent the escape of sewer gas, and this should be enforced by official inspection and adequate penalty. Whenever the grades of the sewers are such that water must be forced through said sewers to keep them clear, every house

drain should be provided with a check valve to prevent back flow during flushing. In other cases the check valves may be omitted, and each house drain be connected with a pipe running to the top of the house or higher, furnishing the sewer with breathing tubes every few feet. The upper ends of these pipes should be kept away from windows and from chimney tops also, where fires are not constant. Except in cold weather, the air in the sewers is cooler and heavier than the atmosphere, and, as the running sewerage draws in and carries with it, *down the grade*, a large amount of air (except when the sewers are much too large), the flow through these breathing tubes is usually, if not always, inward, and no disagreeable odors find their way from them into houses or streets. No right angle nor curve of too short radius should be allowed in the plumbing, and all openings should be smaller than the pipes into which they lead, to prevent admission of substances too large to pass through into the sewer.

Four-inch pipes are large enough for the drainage of private dwellings, and six-inch mains for the service of 500 to 1,000 persons, and for one-tenth of a mile to one-fourth mile of street, according to grade and density of population. Wherever the grades are such as to obviate the necessity for flushing with force pumps, or of exhausting with suction-pumps, a flushing tank, holding from 100 to 300 gallons, should be discharged into the head of each sewer as often as once in 24 hours.

When suction pumps are used to exhaust from the sewers, each house drain should be provided with a valve for temporarily shutting off connection with the sewer, so that the full power of the pumps may be applied to the contents of any choked portion of the sewers should this ever prove necessary.

In Memphis, where the Waring system has been adopted, a hollow iron ball is occasionally sent through the pipes in addition to the flushing. This ball is about two-thirds the

diameter of the pipe and rolls along the top, the sewerage passing below and cutting away any matter that may have found lodgment. In connection with Field's flushing tanks, which act automatically and may be adjusted to discharge as often as desired, this "pill" is sufficient for the most obstinate constipation, where the pipes are of the proper size and grade, and larger than the openings that lead into them.

Of the various pneumatic systems, reference is made by Mr. Hall to the Liernur only. This consists of a steam engine and air pump, maintaining about a two-thirds vacuum in iron reservoirs below the floor of the central station. These reservoirs are connected with smaller ones in each street, and these with pipes running up and down the streets, these pipes being connected by short lateral piping with closets usually in backyards, the odors from these closets being too overpowering for indoor toleration. All junctions of pipes with reservoirs are provided with valves for opening and closing connection between the closets and reservoirs, so that by opening the valves of a given section all closets in this section are connected with the vacuum of the central reservoir and simultaneously discharged. At the central station the sewerage is put into barrels, carted out into the country and sold to the farmers, who purchase only at certain seasons of the year. At other times the sewerage is transported in lighters to some point outside the city limits and dumped into the water. This system is used for the disposal of human excrete only. It is ingenious, but all attempts to manufacture and sell *poudrette*, which is a part of the system, have met with little success. It seems to merit no higher commendation than that in some towns, too low for water carriage of sewerage by gravitation, where no system whatever was in vogue, it has proved much better than none. Even in these cases, it is very expensive, and leaves the rainfall and surface drainage still to be provided for, as do all other separate systems.

The Shone system consists of three separate parts; collecting sewers, receiving house and other sewerage and conveying them to a central station; a sewerage ejector, which is the principal feature of the system; and a sealed main through which the sewerage is forced by compressed air to the place of outfall. This sealed main communicates with the service sewers only through the ejectors, which form complete traps. At Wrexham, England, where the system has been in successful use for several years (longer, I think, than in any other city), the sewerage is discharged through 5-inch iron and 6-inch silicated stone pipes, and here, or in Paris (I am not sure which) to a height of 35 feet.

The Berlier system, so far as I can remember, closely resembles the Shone, and these two are the only pneumatic systems that can be said to be satisfactory in operation and free from bad odors.

Intimately connected with the disposal of rainfall and surface drainage, is the proper pavement of streets, whether a double or single system is adopted. When cobble or other stone is laid directly upon the ground, the concussion of every horse-shoe and vehicle abrades the surface of rock, and shoe and tire, pounds the separate stones into the earth, forcing up between them large quantities of dust to mix with particles of iron, stone and litter, and be blown into our houses and faces and eyes, taken into our lungs, and washed into our sewers. The silt basins at the street corners are usually so small and of such unskillful design and construction as to be of little use; and choking of sewers with attendant ills, result from this and other causes so frequently as to be considered almost a matter of course; whereas they are simply evidences of incompetency, rascality, or unwise economy. But, so long as streets and sewers are under the control of those intolerant of the opinion of engineers, ignorant of the first principles of correct construction, or unable, or unwilling, to meet the necessary expense, these evils from which so many cities are always suffering, are not likely to be much abated.

Passing many points that I must forbear noticing, to the question of sewerage irrigation, I give a few facts, of more value than much theory. In our own country these facts are few indeed. At the State Lunatic Asylum, Worcester, Mass., the sewerage was first applied by surface irrigation to land one-half mile from the buildings. The resulting odors were so slight that this remote application was abandoned and the sewerage is now applied with no disagreeable results to the lawns and gardens in immediate proximity to the asylum and residence of the Superintendent. Similar surface irrigation with similar results is employed at Danvers, Mass. At Lenox, Mr. Field's flush tank, with sub-surface irrigation, is applied to the sewerage of about 25 houses, having a population of perhaps 150 person in winter, and 500 in summer. During the winter the sewerage runs over the surface of the ground. The distributing pipes often get clogged and have to be taken up and cleaned. Loud complaints of stench from flush-tank and man-holes, are frequent. At the Massachusetts Reformatory for women, a similar sub-surface irrigation is in use, with similarly disagreeable results. A few other instances on a small scale, with satisfactory surface and unsatisfactory sub-surface sewerage irrigation, comprises all the remaining data that now occurs to me in the United States.

Ever since the beginning of this century, perhaps from even an earlier period, the sewerage of Edinburg in Scotland, has been applied to Lochend consisting of 18 acres, over and through which it flows to the Craigentinny meadows, two miles from the centre of the town. These meadows contain 200 acres of grass-land; produce 30 tons per annum, per acre; rent for $125 to $225 per acre from April 11 to October 20, and usually bring in about $50 per annum per acre in addition to the foregoing rent. The demand for this land is so great that it is re-let each year. It is of a sandy, friable character, and slopes gradually toward the sea into which it drains. The sewerage is conveyed in sewers

to within one mile of the meadows, and thence in an open ditch, from which lateral distributing ditches are arranged to irrigate any portion at will. The sewerage is allowed to flow over each plat for about ten hours, and about once in six weeks. The grass is cut three or four times per annum. No difficulty is experienced in winter, even when the meadows are covered with several inches of ice. Except when standing directly over or within a few feet of the ditches, little offensive odor is perceptible. Some, though not much complaint has been made of foul odors at the end of the sewer. This might be obviated by a proper system of aeration. The sewerage is much diluted with water. Solids accumulating in the ditches are removed each winter by hand, to keep the ditches from filling up, and are sold for the fertilization of adjoining lands, though after long exposure to the action of water, these deposits retain but small manurial value. While the airs from these meadows can scarcely be likened to

> "Sabian odours from the spicy shore
> Of Arabie the blest,"

they are not unhealthful, are seldom even mildly offensive, and no malarial or zymotic diseases are traceable thereto.

The sewerage farm at Croydon, England, contains about 320 acres. It has been in use about thirty years. Very little disagreeable odor is perceptible even on land entirely submerged. The population of Croydon is about 80,000. In 1855-6, the deaths from typhoid fever were not less than 2,000. In severe outbreaks of typhoid in England, the death rate is as high as 1 in 6 or 8. This would indicate from 12,000 to 16,000 cases, the excreta from all of which passed through the sewers and was applied to the irrigation farm. At Beddington, where this farm is situated, there is a cluster of eighty houses, all inhabited, the inmates of which receive their water from shallow wells fed in part from the efflux water of the farm, as these wells fluctuate with the application of sewerage. Yet the water is not bad,

and not a single case of typhoid occurred in any of these houses. The annual death rate of Croydon has decreased to about fifteen per thousand, and that of Beddington to fourteen, making them among the most healthful places in the world; and Beddington is fast filling up with the villas of London capitalists.*

The highest annual, and the highest zymotic death rate (1871) occurred in London, when the impurities of the Thames and Lee were below the average. The lowest death rate in London occurred in 1872, when the impurities of the Thames and Lee were above the average. The lowest zymotic death rate in London occurred in 1879, when all the sources of water-supply contained impurities above the average.

In 1848-9, when the cholera was raging at Bilston and Wolvehampton, so that large numbers of people encamped out of town, the water from these towns flowed twenty miles down the Tame to Birmingham, the water supply of which came from the river. But there was no cholera at Birmingham.

So many cases of a similar character can be cited that it seems desirable to reconstruct some of our theories in regard to sewerage liquids. But, before attempting anything of this character, let us briefly notice some of the cases relied upon to prove sewerage irrigation a menace and peril too great for toleration. A well in Caterham, England, had been poisoned by a small amount of excrement from a sick person employed to dig it. Pipes were connected with this well, and the water supply of the town drawn therefrom. Soon after, 362 inhabitants of the town contracted typhoid fever. Medical works abound in accounts of typhoid contracted from spring or well water contaminated by contents of old closet vaults in the immediate vicinity; and in some cases, from vaults at a distance of several miles, these vaults

*See "Discussion of Potable Water." Min., Proc. Inst. C. E. Vol. 68, 1881-2.

being in close proximity to the vein or underground stream that fed the well or spring.

About one mile south of Lausen, a healthy mountain village near Basel, Switzerland, and separated from this village by the mountainous ridge of Stockholden, lies a small parallel valley. In an isolated farm house in this valley, a farmer just returned from a long journey, was attacked by typhoid on the 10th of June. Within two months two other cases occurred in the same house. A small brook, passing by the house (near the closet and dunghill), into which all the slops of the chambers were emptied, and in which the dirty linen of the patients were washed, was annually used for the irrigation of the meadows below the house, which this year were irrigated from the middle to the end of July. On the 7th of August, ten of the villagers of Lausen were stricken down with typhoid fever. During the next nine days fifty-seven cases occurred, out of seven hundred persons living in ninety houses. In four weeks, one hundred cases, and by the end of October one hundred and thirty cases had occurred—seventeen per cent. of the entire population. The inhabitants of six houses who were supplied with water from their own wells, were entirely exempt. This led to a suspicion that the public water supply was contaminated. It came from a spring at the foot of the Stockholden ridge. Ten years before, by giving way of soil in the meadow below the farm house referred to, a hole eight feet deep and three feet in diameter, was formed, across the bottom of which, a small stream of clear water was running. The brook on being turned into this hole, entirely disappeared, but in an hour or two the spring at Lausen suddenly overflowed with great abundance of turbid water, which soon became clear. This unwonted flow continued until the brook was again confined to its bed. It was noticed ever after, that whenever irrigation of the meadows below the farm house occurred, the water supply of Lausen soon became much augmented. Inquiry developed the fact (of which the villagers

were ignorant), that these three cases of typhoid had occurred at the farm house. The hole mentioned was reopened and the brook again turned in with the same results as before. About one ton of salt was then dumped into the hole. In two or three hours the spring at Lausen became very salt, proving its underground connection with the irrigated meadows.

In all these, and so far as I know, in all other cases of typhoid arising from the use of contaminated water, the excreta had laid for weeks, generally for months, sometimes for centuries even, before admixture with the waters that caused the disease. It had become old. Its seeds of death had matured. It had generally, perhaps always, passed slowly, in darkness, through pipes or underground channels to the place of use; while in properly conducted sewerage irrigation, the excreta is quickly diluted with water rapidly swept through the sewers out into the air, and light, and sunshine, spread over a broad surface, filtered through the soil, and within forty-eight hours passed out into some watercourse or water-bearing stratum in a harmless condition; its germs of mischief, so far as we can discover, dispersed and destroyed.

After a proper sewerage irrigation system has been in use for a few years, old prejudices die out, and old opponents become advocates of the system. Unfortunately, in many cases it has been sought to dispose of the sewerage on too limited areas, and intolerable nuisances have been the result. The same evil follows its application to unsuitable ground, and apparently to all cases where sub-surface irrigation is employed, whatever the nature of the ground.

The sewerage farm at Berlin is described as "a slough of despond into which cattle sink to their knees refusing to eat the grass," only because the farm is too small for so large a city, and the ground of an unfavorable character. Clayey ground has given good results only when thoroughly prepared and underdrained to the depth of from four to eight

feet. The sewerage passes through with little permanent enrichment of soil. Whatever is not absorbed by the roots of growing crops, seems to be wasted. Hence, to utilize its full manurial value, it should be distributed over a much wider area than has usually been the case. In England, twenty-two towns with sewerage farms have an average of 111 persons to each irrigated acre. This is sufficient, in most cases, for sanitary purposes, but not for obtaining the full manurial value of sewerge. In California, the sewerage should be diluted with all the water required for the irrigation of the farm, and the farm should be *large*, so that the dilute sewerage would form a weak solution.

In discussing a paper referring to so many subjects, on most of which one might talk for days, one scarcely knows where to begin or stop; but I have spoken much longer than I intended, and perhaps longer than my doctor would think that I ought.

Mr. Harold Wheeler said he wished to call the attention of the Society to the fact that the discussion of the sewage question, both by Mr. Hall in his paper and in the oral discussion that had followed, had been limited to the problem of how to get rid of the sewage of cities, while the problem of how to save and utilize the sewage had been passed by. Mr. Hall had advocated a system of sewage irrigation, not so much from the fact that a large amount of valuable material might be thereby saved as that a large amount of noxious material might be thereby destroyed; and had seemed to accept with satisfaction a system of drainage, for seaboard towns, which would carry the sewage well out to sea. The other aspect of the question, however—the problem of utilizing the manurial properties of sewage—was of quite as great importance—of enormous importance, indeed, when the vast amount of sewage that is daily wasted is considered. In California, this year, the wheat crop alone will amount to nearly 1,500,000 tons, a large part of which, of course, rep-

resents so much weight of the ingredients of the soil which are necessary to the support of organic life; and the ingredients thus taken from the soil are never returned to it, if the sewage into which this wheat is largely converted is not in some way utilized as manure. Communities which export agricultural produce must of necessity exhaust their soils, but there ought to be some compensating enrichment at the places where the agricultural produce is consumed. But in fact there is little or none, no civilized country having yet done much towards checking the flow of its sewage out to sea. The land of the world is gradually pouring its life-giving materials into the ocean, and gets absolutely no return except the insignificant one of the fish catch, the kelp harvest, and the guano yield of the sea-fowl. The result, without an economical reform, will be the exhaustion of the face of the earth.

Already the standard of fertility throughout all the Eastern States of America has been seriously lowered, while many parts of the earth have long since been absolutely exhausted. The labor expended upon the pyramids of Egypt and upon the cities of Babylon and Nineveh give a hint of the fertility which must have once existed where now are barren sands. What was the cause of the change? If the Star of Empire has taken its way Westward — if the great civilizations of antiquity have faded from the earth — is it not largely because they, too, pursued the same improvident course that we are now pursuing—exhausted their soils and made no return to it? Historians are apt to ascribe the declines of empires to moral causes, to social dissensions, corruption of courts, sensuality of the masses. Are not these rather only the symptoms of the decline itself, and, like the latter, only the effect of the physical exhaustion of the country?

It may be worth noting that China—the only great country whose star of empire has not faded or set—the only empire whose population has perpetuated itself and its institu-

tions from the most ancient to the most modern historical times—is also the only country in which, if report is true, it has always been the custom to utilize the refuse and the sewage in the manuring of the land.

DISCUSSION OF MR. HANSCOM'S PAPER ON CABLE RAILWAY PROPULSION.

[Mr. Hanscom's paper was read June 6, 1884, and was published on pages 63 *et seq.* in the Transactions of the Society, Vol. I, No. 2.]

Mr. Dickie—I would like to ask Mr. Hanscom if he formed any opinion during his investigations, as to the best method of transmitting power to the rope. There are three or four methods in use here. I should like to hear what Mr. Hanscom has to say on that point; and whether in his investigations he has arrived at any conclusion as to the best system.

Mr. Hanscom—Although I gave that part of the subject some attention, I did not consider it proper to give any opinion, as my paper was merely descriptive, and my object was more particularly to give some data as to the power used on these cable roads. On the Clay street road, they use a clip pulley, which is on the principle of that used in the Fowler system of steam plowing. This same system is in use on the Presidio road. The California street road uses what is known as the "figure 8" plan. The rope passes over one drum three quarters of the way and is led from the bottom of this over another, around three quarters of the way and back to a sheave having a weight to it. This is the same way the power is transmitted to the rope on the incline

at the Gordon Plane in Pennsylvania. It must work satisfactorily, for they put it in use on the Market street road. They also changed from another system to this "figure 8" on the Sutter street line. It is more properly called the Bishops Derrick system. The Sutter street road had this system when first starting, but they had some trouble with it, I think; perhaps from the creeping of the rope, or wearing in the grooves. At any rate, when they put in their new engine, they adopted the system in use on the California street line. The Geary street road still uses that gear. I do not know how satisfactory it is. Mr. Dickie is perhaps better informed on this point, as the Union Iron Works built the engines, and he has had more or less to do with the road. I have no personal acquaintance with the managers, and have had no opportunity to make any examination. On the Market street, and to a less degree on the Sutter street, there is a wearing of the groove in the drum, which is lined with wood. If the groove on one drum wears faster than that on the other, there will be a slipping of the rope, but whether this will correct itself gradually, I do not know. With the plan in use on the Clay street and the Presidio roads, they appear to be well satisfied; but these ropes are not so heavy, large or long as the Market street rope. It is difficult to make any comparison between the systems where the work on the roads is not uniform.

Mr. Dickie—The question of the transmission of power to the rope is one of the most interesting in the cable system. I do not know that there has been data collected as to the effect of the different systems. The difficulty with the drum system is the unequal wear in the grooves and the binding of the rope because of the greater velocity of one or the other. I do not know whether any experiments have been made as to the effect of this wear. It has a bad effect on the wear of the rope. On the Geary street they have had four or five new ropes since they started. It used to be a

chronic trouble on the Sutter street road. I think the method that will have the best effect as to the power required, is the grip pulley. If the construction of the pulley is perfect, I think there is no doubt that the grip-pulley method of driving the rope will require the least power. I thought perhaps Mr. Hanscom had collected some data on this subject. I think Mr. Hanscom's paper is a valuable addition to our knowledge on the subject of cable roads. In fact, there is no literature on the subject. I have some data collected, but it is not yet in a presentable shape.

Mr. Hanscom—I would like to ask Mr. Dickie a question. I gave an estimate of the power required on the Sutter street road. As he is in a position to know, I would like him to tell me what power is required for the rope alone; how does my estimate compare with the true power?

Mr. Dickie—During a run of four hours on the Sutter street road early one morning, I took 24 cards. The time between cards was an average of about ten minutes. As to whether the results would represent the mean of the power, I would not like to decide on such a short run, and with such a limited number of cards. The cards vary very much. The mean of the cards gave 177 horse power, which is probably as near as the ordinary manner of taking cards would show. But I would not accept it as true, because the variation was so excessive, and these variations do not seem to follow each other in any regular order. The mean of 24 cards with the empty rope gave 177 horse power.

Mr. Hanscom—If this is a fair mean, then my estimate was out of the way. My estimate was less than one half of this figure. It was based on the average of the California, Presidio, and Clay street roads. I gave it at about 80.

Mr. Dickie—At the time I made the test there was a new rope in use and this of course made some difference. The tension was very heavy on the Larkin street branch. The

curves absorb a large amount of power. In a rough way each of these curves is estimated to take about 28-horse power. This is as near as we can gather; that is in comparing it with the weight of a rope on a straight road and comparing the weight of rope in motion on both roads. This is of course a rough way of determining the question. The friction cards, inside the engine house, when there was no rope on, gave 33½ mean horse power.

Mr. Hanscom—The McAllister street road, with 25,000 feet of 1¼-inch rope, runs the lightest of any in the city. They have in use the same Figure 8 system that the Market and Sutter street roads have, but the power required was less than my estimate. I took cards from that engine with two different indicators, the Richards and the Tabor, to satisfy myself that the cards were correct, as the first cards showed much less power than my estimate. The Tabor indicator gives a little less than the Richards. It is possible that the momentum of the moving parts of the Richards indicator would carry it higher, but at all events this rope showed less absorption of power. Yet in one place they have a sharp angle or curve at a point where the cable goes immediately under a depression pulley. I think with Mr. Dickie, that there is a great deal in the manner of putting in the carrying pulleys and keeping them in order. On one occasion they found—on the McAllister street road—that one of the pulleys on the hill was stuck fast, and it was shown in the engine house by the consumption of coal. If the men who oil these pulleys take good care of them, much waste of power can be saved. The Clay street road showed the most friction of any I examined, though I think that the Sutter street road has really the most.

Mr. Bowers—I have been familiar for some years with the clip drum used in the Fowler plowing system, though not with the Hallidie drum. Are not the Hallidie drums expensive to keep in order? I should think the wearing parts or clips would require very frequent renewal.

Mr. Hanscom—There is no great amount of trouble from this source. The wear on those roads where the clips are used is small. It is a simple matter to renew them, as the castings are cheap and it costs less to put in cast clips than the wooden linings of the drum system.

Mr. Bowers—Are not the combined angles of the curves on the McAllister street branch about equal to one right angle of the Sutter street road, and how many right angles are there on the Sutter street route?

Mr. Hanscom—On McAllister street each curve is about equal to one-half of a curve on Sutter street—that is, each curve on Sutter street is one-fourth of a circle, while on McAllister it is only one-eighth of a circle. There are four of these curves near the engine-house on McAllister street and one curve at the junction of McAllister with Market. The Sutter street has four curves on Post street, so that the total length of curves on McAllister street is five-eighths of those on the Sutter street. The cable on McAllister street is larger and heavier than on Sutter street; the sheaves are somewhat farther apart on McAllister street than on Sutter street, and the speed on McAllister street is eight miles per hour, and on Sutter street it is a little over seven.

Mr. Dickie—The Sutter street road runs a little short of eight miles. The speed of the Market and Sutter street roads is about equal.

Mr. Hanscom—The Larkin runs a trifle slower than the Sutter street.

Mr. Dickie—There is $\frac{5}{8}$ of a mile difference in speed of the ropes. It is about $7\frac{1}{4}$ miles on the Larkin.

Mr. Bowers—I have noticed that many of the small bearing-pulleys in the tubes are rough and the journals and bearings are badly made. I think the greatest improvement now

to be made in this system, lies in diminishing the power by smoothing the pulleys and polishing the bearings and journals. All the moving parts where there is friction should be made smooth.

Mr. Hanscom—If the information in my paper was noted by the Sutter street people, they would save money. If the pulleys, etc., are taking twice as much power as they should, it would be a good thing to look the road over and remedy the defects. The engine seems all right, but the pulleys are in bad condition apparently, for a great deal of power is consumed. Any one can tell the speed when they count the blocks which are 412½ feet. There is not much slip of the grip on the rope. Even on a steep hill, there is very little slip.

Mr. Bowers—I have seen a grip which I think is called the Taylor grip. It seems a good design, though I have not examined it very critically. It consists of two endless chains with grooves in the links which clasp the rope and run with it without slipping, the wear coming upon the chain and jaws of the grip around which the endless chains run until the grip is tight enough to hold them. I would like to inquire whether this grip has ever been tested?

Mr. Hanscom—I know of this grip, but I do not think it has been tried. It is something on the plan of Mr. Brandling's device, which was patented in 1845. He had three large pulleys, and the endless rope ran between the peripheries of the pulleys. This is the nearest to the simple roller grip.

Mr. Yale—I believe that the objection to grips having rollers which are caused to close and grip the rope is that there is a very small bearing surface on the rope. These ropes, after running awhile, become brittle on the outer surface, and the pinch of these rollers is apt to injure the rope.

I am informed by Mr. Root, constructing engineer of the Market street road, that such is the case. On that road, where they have a grip which had removable dies to take the wear, they first tried putting wood in the grip—a patent for which was taken out by Governor Stanford and Mr. Root. But this was found to be impracticable, because small splinters of wood kept getting into the strands of the rope and making lumps. Then they made the dies of soft brass. These worked very well, but were rather expensive. They finally settled on soft cast-iron for the dies. They are said to answer as well as the brass and are very much cheaper. These dies are easily removed and renewed. They are not found to wear the rope to any appreciable extent.

Mr. Hanscom—The length of surface of the jaws of the grip has an effect on the wear of the rope. The shortest dies are those on the Clay street road, 3½ inches, I believe. There are some in use, however, over 8 inches. Those on the Market street are 12 inches, and the same on the Sutter street. The Chicago roads have the dies about two feet long, but they use wood in Chicago. I think they may have had to put in iron since the road was started. I was informed that the old Sutter street engines took 120 horse power to move the ropes.

Mr. Dickie—I think that is nearly correct The condition of that road has been injurious to the rope. It is only the middle of the road that is in good condition. When it is all in good shape there should not be so much friction. There is one thing, however, the power required for moving the cable depends to a great extent on the condition of the moving part on the road bed—the pulleys generally. At the time they were running on the Sutter street road a change that was made caused a reduction of 40 horse power as the mean of cards taken in one hour at five minute intervals. They had been using a certain quality of oil that gummed and hardened, and on one day four of the large pulleys

froze. The high rate of power was chargeable to some extent to the poor lubricant. The quality of oil, the time of oiling, etc., have an effect, so much so that it is difficult to get any data which will agree one day with the other. According to Mr. Eckert's record, the lowest record on the Sutter street road was 103 horse power for moving the rope. Another thing, is getting the mean of power from a compound engine. You cannot get the power to correspond with a mean of 20 cards for both cylinders. I hardly think it possible, without a continuous indicator on each cylinder, to arrive at the exact power of these compound engines. One morning I took cards which ran from 106 to 280 horse power. There seemed to be a wave action in the rope that continually varied. This was not due to the action of the governor, for I endeavored to keep the engine at work without the governor. There was no rhythm to it. There is no difficulty in governing the engines. On the Sutter street road, where power for the electric light was obtained from a pulley on the main engine shaft there was no unsteadiness of the light, and this light is quite sensitive to variations. The engine was running perfectly steady, though taking steam at one end only, one of the valves being out of order at the time.

Mr. Hanscom—Did you uncouple one engine?

Mr. Dickie—Yes. I took one side only. But this had no marked effect on the variation. Once in awhile we would get cards where the variation was not so great. The variation on the McAllister street road was from 56 to 208 during the day with the cars.

Mr. Hanscom—The Union runs from 10 up to 200 for the variation of road during the day.

Mr. Dickie—These variations are due to conditions in the road outside of the engine house, and it is difficult to tell where.

Mr. Hanscom—Why does it take more power to run the Sutter street road than it did with an old engine?

Mr. Dickie—They have now a larger and a heavier rope, and the old engine had no work on the section at Lone Mountain.

Mr. Bowers—It would seem where the variation is so great there must be something wrong with the pulleys. They must sometimes run free and at other times be stuck. Or the rope may get out of the pulleys and drag on the bottom or along the top of the tube, as the case may be.

Mr. Hanscom—The power required on the Market street road is about the same as that at Chicago. It corresponds also very nearly with that on the roads in New Zealand. In Philadelphia, when they started they had 8000 feet of rope, and the engineer said it took 100 horse power to move the rope alone, nearly five times as much as is taken on the Clay street hill road in this city. They had probably the best pair of engines in the United States to run the road, too. I think there is a broad field of investigation in the proper method of carrying the rope in the tube. A great number of carrying sheaves badly put down produce expensive results.

Mr. Dickie—It would be interesting to find out the relative increase of power with the speed; say to indicate the engine from a speed of rope of four miles per hour up to eight miles and find out the increase.

Mr. Hanscom—It would be difficult for us to get at this, because no two ropes here run under the some conditions. Did you say, Mr. Dickie, that with either the high or low cylinder the average power was the same as with the two cylinders combined?

Mr. Dickie—Yes. No effort was made to find out what could be got with each engine. With either cylinder alone the consumption of fuel was much increased.

Mr. Hanscom—In taking my cards I held the governor wide open so as to get the maximum pressure of steam. On the Market street engine we got a little more with two engines than we did with one alone when holding the governor open to get the maximum pressure in the high cylinder.

Mr. Bowers—It seems to me that valuable information would be gained in trying different rates of speed, say from 20 up to 100 revolutions of the engine.

Mr. Hoadley—In my experience with another class of road we found the only variation of power in moving the load was in the atmosphere. I recollect it took eight pounds pressure to move one ton on a dead level. In a speed of from eight to fifty miles there was no difference except that due to the atmosphere. A weighing machine attached to the car showed this. We balanced a car on a wheel adjusted to stand exactly on the center, and it did not make any difference whether the wheel made 10 or 100 revolutions. I think the difference in the cable roads is mainly in the condition of the track and in the loads. When the cars go down hill loaded, of course the engine needs no steam.

Mr. Hanscom—The cards I took for the Clay street road were with the old rope, and with the new one it took 8 per cent. more. After it was in use seven or eight weeks, there was no difference from that that was in use seventeen or eighteen months. In the calculation I made to move the cars I allowed twenty pounds per ton, and from information I got from running cars on a light grade. On the Market street road they will run—not start—on a grade of one per cent. This is what I have assumed under the usual conditions of the rails in the streets. Of course, where there is a grade of two per cent., it takes double the power. When there is a grade of 18 per cent., it is like taking 18 cars up a grade of 1 per cent. When this comes on suddenly, it makes a great difference in the power. The greatest fluctuation of power is on the Union street road. There it runs

from 10 horse-power up to 207 or 208. When the cars are all off, the rope runs steadily. So on the California street, and so on the McAllister. The Market street has some variation. On the Sutter street, I think it takes nearly as much power for the rope as on the Market street, while the Market street road has about twice as much rope. The California street rope is about 1¼ inches in diameter.

As to the life of a rope, which is a somewhat important question, I said but little in my paper. The conditions under which they run are so different in this city, and the care they receive so different. On the Clay street road, the first rope lasted the longest. It lasted two years and three months. The last rope lasted twenty-one months, but it had more work and wear, owing to the line running longer hours. The traffic is, however, uniform, and there are not so many stops necessary as on the Market street road, which has the hardest wear of any in the city, on account of the frequent stops. The rope which runs from the engine-house to the ferry wore out in six months, while that from the engine-house to Twenty-eighth street was in good condition at the same period. This is on the same road. but the latter rope has not to stand so many stops and starts.

Mr. Hoadley—The first cable on California street from the Larkin street terminus, lasted only four months, and the other ropes lasted three or four times as long. This was on account of the difference of material.

Mr. Hanscom—They tried several kinds of material on Calfornia street. The best results are crucible steel rope. The now rope they have now was made in Germany. The interior portions of the cable are made of finer wires and more of them. It is thus made more flexible. All of these ropes have hemp cores. The first part that gives out is the splice. The ends work out, get caught in the grip and bunch up.

Mr. Specht—We all agree with Mr. Dickie as to the value

of Mr. Hanscom's paper, and the thanks of the Society are due to him for his contribution to knowledge on this important subject. We hope Mr. Hanscom will continue it on some future occasion.

Mr. Hanscom—I was afraid my paper would be too voluminous if I went into further details. Moreover, the companies have not all a disposition to let the detail of their work be made public. I could not get cards from some of the engines. So far as the consumption of fuel is concerned, they keep that matter to themselves.

Mr. Bowers—Mr. Dickie has some information on the subject, which he ought to give us if possible.

Mr. Hanscom—I think he is the very man to do this. He probably has much data on the Sutter street road, from which I was unable to obtain any.

Mr. Dickie—I should be pleased to give Mr. Hanscom all the data I have. He has treated the subject very ably, and he is welcome to all the information I possess. As to the consumption of fuel on the Sutter street road for the past four months, it has averaged five tons and 1700 pounds. I do not know that there was any difficulty with the engines on this road. The old engine broke down before the new one was ready, and the new engines had to be completed while at work. Moreover, they had to be run for sixty days before they would be accepted; during which time Mr. Eckart had charge of them. The difficulty in getting data from the managers of the roads is, perhaps, because they have no data, and do not like to say so. They know all about how many passengers they carry, but are not so clear on other points.

Mr. Bowers—The difficulty in getting data in most cases arises from the fact that there is no data to be given. In

no other way can we account for the use of so many bad engines and boilers, and other machinery. Steam users make but few tests and do not know the defects of their machinery. Our manufacturers would all prefer to furnish first-class engines and boilers and keep up with the times, but most steam users prefer old style engines made from old patterns, rather than to pay a little more for good ones. They buy the engine that costs the least regardless of the cost of running. This would not be the case, if they made tests and had data.

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THE TREATMENT OF SEDIMENT-CARRYING MOUNTAIN STREAMS IN EUROPE AND ITS APPLICATION TO CALIFORNIA.

BY GEO. J. SPECHT, M. TECH. SOC.

Read July 11, 1884.

Introductory Remarks—The debris question, so important to the interests of this State, is full of interesting features. It is of such intricate and complicate nature, that only the most careful and impartial investigations of all the conditions bearing upon it can bring about its successful solution. The desire to contribute a small share to such has moved the writer to investigate what has been done in reference to sediment-carrying rivers, torrential streams, etc., in other parts of the world. The Alps in the southern and central part of Europe afford the best opportunity to study this question as they have a great many such water-courses, which have damaged and partially continue to destroy the valleys by raising the river bed and destroying adjoining agricultural lands by erosion or filling in. Certain portions of these, however, have been very successfully improved by comparatively simple and inexpensive means. The source of the detritus there is natural wash, and in no case hydraulic mining.

In California the conditions are somewhat different, since the natural as well as the artificial source of the detritus must be considered. Appreciating fully this difference, it is nevertheless apparent that a study of the works of European engineers, in reference to the permanent improvement of sediment carrying water-courses, cannot fail to be of service to those engaged in the solution of this question in California. Taking advantage of this experience and modifying their measures according to local conditions, more satifactory results will be obtained than if the same were ignored. No originality is claimed for that part of

this paper, still the writer hopes it will be agreeable to the members of the Technical Society and will give rise to a thorough and careful discussion and investigation on the part of this society, of one of the most important questions in California.

Characteristics of Torrential Streams—Before entering upon an account of the remedies applied, it is necessary to look into the general nature of torrential streams.

1. *Origin.*—The constant influence of the atmosphere, the rains, snows, hail and dews, and the changes of temperature, all affect the materials of which the mountains are composed, and cause a continuous disintegration of their surfaces, which are washed down subsequently by the falling rain. This occurs most rapidly there where the soil is not protected by vegetation. The flowing water cuts a channel in which the detritus is carried to the lower valleys. The disintegration and erosion progresses then more rapidly. The water undermines the slopes, these, losing their equilibrium, slide into the water-course and are carried away by the water. The bed becomes wider and deeper, new tributaries are formed until a large number of them cover the whole water-shed.

2. *Clas·ification.*—The torrential streams can be classified conveniently as follows:

a. *Simple torrential streams*, having but one main gorge or valley into which a smaller or greater number of secondary tributaries issue.

b. *Compound torrential streams*, which have two or more main gorges or valleys, or are composed of several simple torrential streams.

c. *Fan-shaped erosions* on the slope of the mountains. Here one deep erosion is fed by a large number of smaller ones, they are generally dry, except during the rainy season.

3. *Subdivisions* —To whatever class the torrents belong, they all show three or four distinct subdivisions:

a. *Region of erosion*—collecting basin. A, B, C, in Fig. 1. This comprises the upper part of the water-shed, where the

Fig 1.

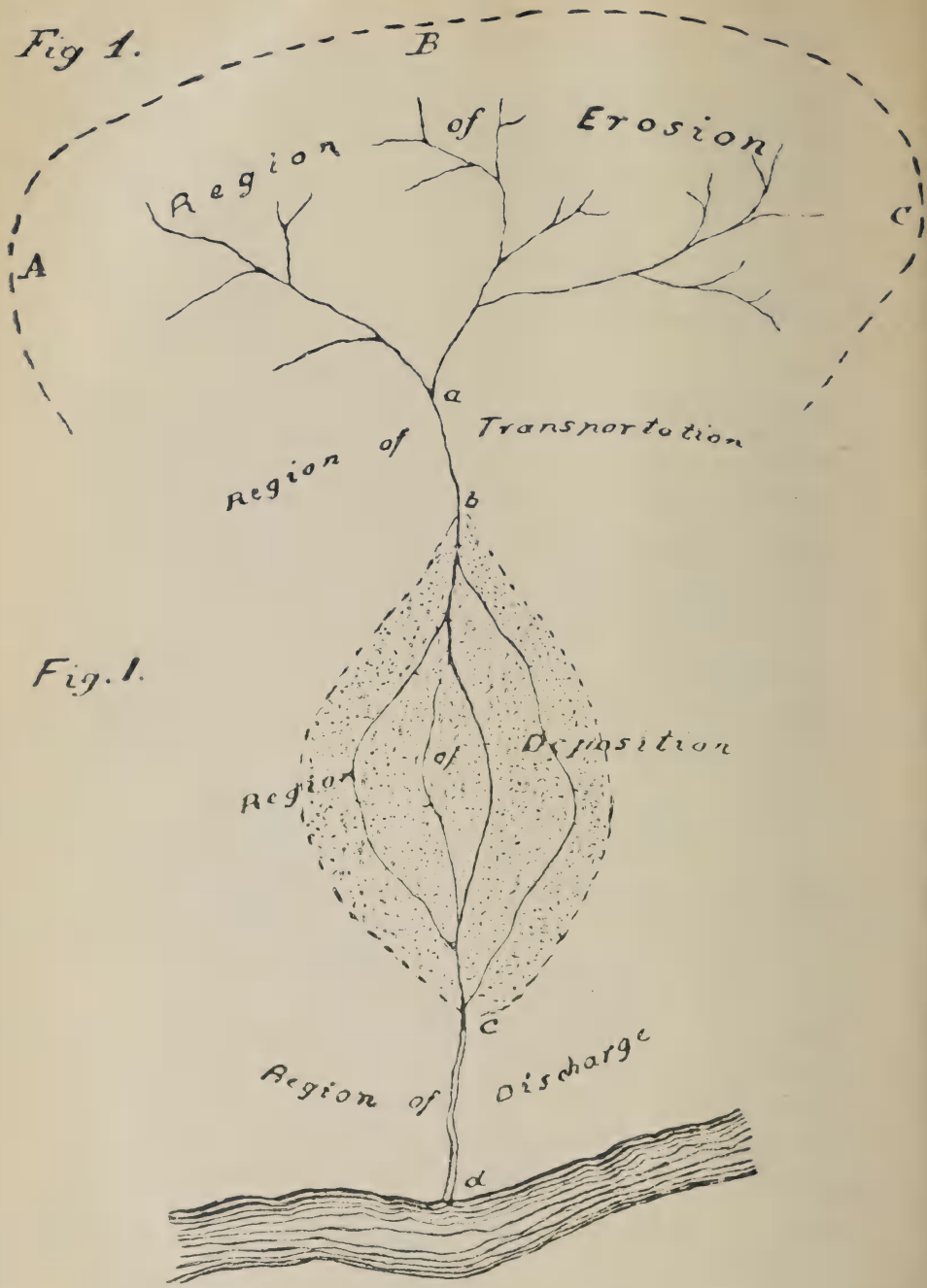

B
Region of Erosion
A
C
a
Region of Transportation
b
Region of Deposition
c
Region of Discharge
d

Fig. 1.

water and the products of disintegration and decomposition are collected, and from which, both combined, are carried into b, *region of transportation* (a b in Fig. 1,) which serves as channel-way to transport the water and the detritus into the c, *region of deposition* (b c in Fig. 1,) which is raised continuously by the settling of detritus. d, *channel of discharge* (c d in Fig. 1,) carries the water from the region of deposition where it left its coarser detritus, to the main river. This section, however, is sometimes missing. All these subdivisions can occur several times in one and the same water-course.

4. *Action of the water in Torrential Streams.*—During the dry season most of these streams are harmless. As soon, however, as warm winds cause a sudden melting of the snow, cloud-bursts occur or a long-lasting rain sets in, the erosion becomes immense A chaotic mass of debris, gravel, rocks and bowlders is carried down by the water to the valley. The volume of the sediment is sometimes several times larger than that of the water. In the beginning all the different classes of detritus are carried along with the same velocity. Soon, however, the large detritus will attain a greater velocity on account of its volume, and will deposit itself wherever a sudden decrease of the grade occurs. The other material will lodge behind them at first in a general disorder, but later on in the order of their respective dimensions. The region of deposit will then assume a *convex* profile. If then the volume and the power of the water should become greater, a reversed action commences, *i. e.* that of the separation of different sized detritus. The water carries now each kind of detritus separately with a velocity inversely proportional to its size. The result is that the fine material will be deposited at the lower edge of the region of deposit and the coarser at or near the apex of the same. The longitudinal profile of this region will then assume a *concave* form, *i. e.* it will be steeper towards the source. This change from a convex to a concave profile will occur after each large rain-storm or melting of snow. The convex profile proves that the stream has just come to a comparative rest. In this way the region of deposit will always be replenished, its grade will

constantly increase, until finally all the material carried to it by the stream loses its equilibrium and is carried farther down the valley. The grade on which this will occur, is called the "*profile of equalization.*" Then only such masses of detritus are transported from the upper region as the region of transportation can carry away. This corresponds to a continuous transportation of detritus in both regions, necessitating a cessation of the above mentioned increase in the grade of the region of deposit.

But this state is not a permanent one, for as soon as the water becomes clearer and enters the region of deposit without being charged with detritus, then a similar process of erosion and transportation will take place, by which the surface of the region of deposit will be lowered more and more, and its slope will become gentler. This will continue as long as the grade is steep enough for the water to carry off the detritus. When, however, the limit of this is reached, and the transporting power of the water and the resistance of the river-bed balance each other, then the stream has "worked out" or becomes dormant; it will discharge only clear water, and the stream has adopted its final profile, the "*profile of equilibrium.*" The profile of the region of transportation is always a concave curve at its lower end. It may, however, have a profile which does not fit into such continuous curve. This is the case when the erosion has reached the bed-rock at several points. Then smaller or larger falls are formed, which interrupt the regularity of the profile. Below and above such places, the regular concave profile will exist.

Means of improving Mountain Streams.—In order to improve torrential streams in a permanent manner it is necessary to determine:

1. How the formation of detritus can be prevented, or at least be decreased?
2. How the detritus can be stored near its sources?

The leading principle of any improvement is to attack the evil at its very source. Small slides and erosions, in their first state of formation, can be stopped easily at little cost, but if allowed

to attain larger dimensions, they become rapidly more powerful, and require much more extensive and costly works.

The improvements requisite are—

1. Such as will prevent the sudden and rapid collection of larger quantities of rain water. This is accomplished by the planting of forests and the raising of grass and underbrush near the sources of the water-courses. Vegetation protects the soil against the mechanical effects of the rain; the roots bind the soil together, and the fallen leaves and the grasses retard the flow of the rain water; the plants absorb the same, and store it for a continuous and regular supply of the springs and water-courses. This will prevent the sudden rises of the rivers.

2. The protection of the shores against undermining, and the bed against erosion. This is principally done by the erection of "Thalsperren." The German word for these structures has been retained, as it is more significant and comprehensive than the English expression, "restraining wall." It includes works which are not walls, but have the same duty, but in a less degree.*

A Thalsperre is a structure erected across the bed of a stream, to diminish the grade of the same and to decrease the power of the water; also to raise and thereby widen the bed; and to retain or store detritus. A distinction is made between "*dead and live thalsperren.*" The first are built of rock, or timber, and the latter of hurdlework and fascines, made of green branches. The latter have that advantage over the former, that their resisting power will increase from year to year, as the branches drive their roots into the river-bottom, and the growing twigs oppose greater obstacles to the water. The thalsperren of rock are either curved or straight. They can be built of dry masonry, or of masonry in mortar, or both. Wooden thalsperren should be used only where stone or rock cannot be obtained economically.

If a series of thalsperren has been built so that the line connecting the foot of the upper one with the top of the lower one corrresponds to the profile of equilibrium, *i. e.* the grade on which the water is not able to carry away any more detritus,

*The definition of the word "Thalsperre" is, a structure which closes up a valley. "Thal" is the German word for valley, and "sperren" for "to close up."

then it is evident that the detritus carried by the torrent will lodge above the thalsperren. If these thalsperren are sufficiently high, and the river-bed has been widened by the deposits, and the water is compelled to run in the centre of the thalweg, away from the shores, then the problem of the permanent improvement of the torrent is solved.

But as the grades of the torrents are generally very steep, the distance between two such thalsperren would be very short, and the number of thalsperren necessary to arrive at the desired result very great, which would involve a heavy expense. Therefore, all what can be accomplished is to create the profile of equalization, and then construct such other additional works, which will prevent the erosion of the deposits and the undermining of the shores.

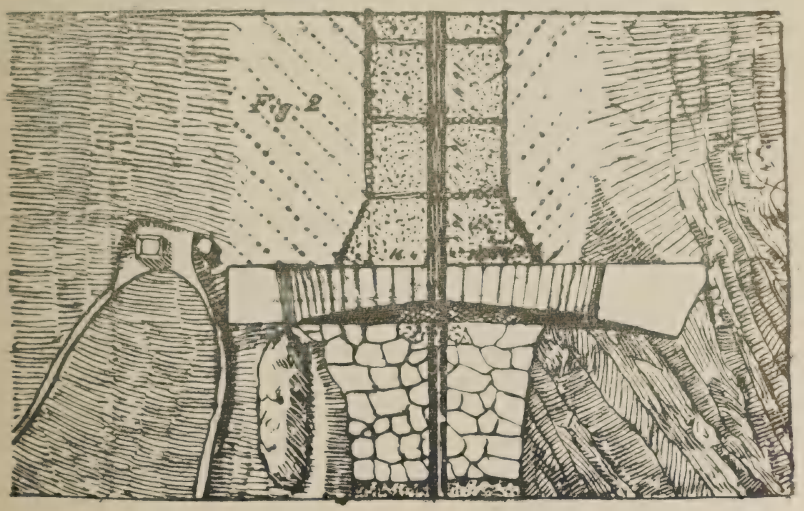
Such works consist generally of strong hurdles erected lengthwise equidistant from the centre line of the thalweg or the future river-bed, and of cross-hurdles placed at regular distances, forming steps, the upper edges of which lie in the line of equalization. To prevent undermining of the cross-hurdles, they should not exceed 1.5′ in height, and the toes should be protected with rocks. The brush in the hurdles soon takes roots and sprouts, thereby securing the river-bed and breaking the power of the high water. The space between the longitudinal hurdles and the shores must be filled with earth and be planted with willows set in rows under an angle of 45° with the centre line of the torrent. Finally trees, driving deep and strong roots, should be planted.

Where stone is abundant, the hurdles are replaced by small thalsperren (2-3′ high) of dry masonry (rustic-thalsperren).

The works so far outlined, have been employed successfully in France; they, however, refer principally to that class of mountain streams which derive their detritus solely by undermining the shores and eroding their own bed.

The other class of mountain streams, which receive their detritus from large accumulations of rocks, formed by the disintegration of the mountains or by glacial action, require additional works to neutralize the damaging influence of the continuous supply of material. These consist in the retention of the same

near its source, or if this is not possible, in its storage near the foot of the mountains. The remedy in the first case is a restraining dam, a large thalsperre (in contradistinction to this kind, the previously mentioned thalsperren are called "consolidation-thalsperren,") built up in the mountains, or in the second case, a storage reservoir for the detritus on the talus of the torrent or at some other convenient place. As the restraining dams are built for the purpose to store as much detritus as possible, it is important that they should be built below places with gentle grades and of large lateral extent. They must be constructed so that they can be raised from time to time, by either putting a new section upon the thalsperre continuing the same slope, or by building a new one a little back of it. This latter method has the advantage that by the succession of steps the power of the falling water is broken; also that in case of injury or break of one of the steps the whole work is not endangered. The above mentioned storage places have the purpose to receive all the detritus not restrained by the upper thalsperre. They consist of dams or levees, enclosing a larger or smaller area, with a wastegate at the lower end, through which the clear water runs off. When the place is filled with detritus, trees are planted and another storage place is prepared.



DETAILED DESCRIPTION OF SOME THALSPERREN.

1. *Thalsperren of masonry.*—Figs. 2 and 3 represent a thalsperre of the perimeter of Bourget in Southern France. It is one of the best examples of this kind. Its length, measured along the crown is 98.5′, its thickness there 9.2′, height above bed of

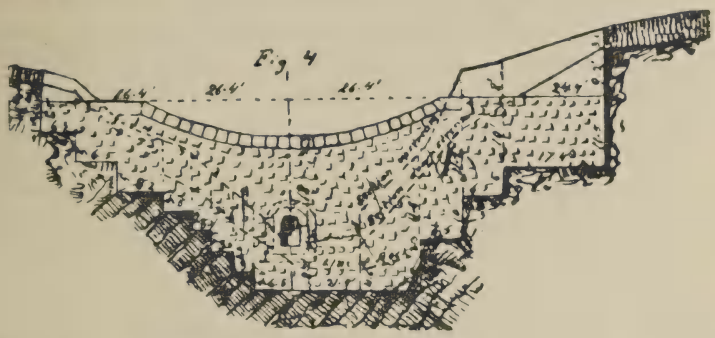
stream 23′, and above bed rock 37.3′. The up-stream slope is vertical and straight, while the down-stream side is built with a concave face and has a slope of one foot horizontal to 5′ vertical. The chord of the upper part of the down-stream side is 65.6′ with a raise of 6.56′; while the lower part has a raise of 3.18′ with the same chord. A culvert 3.28′ wide and 4.92′ high has been built through the thalsperre, level with the bed of the torrent. The down-stream wall is faced with rubble masonry, the crest with cut-stone, and the whole is laid in cement.

The amounts of masonry used were as follows:

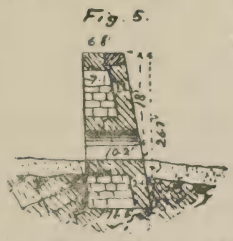
Common rubble masonry	19,378.6	cubic feet.
Masonry of faced rubble	6,771.6	" "
Masonry of cut-stone	1,549.0	" "
Total	27,699.2	cubic feet.

The total cost was $3,098.18.

Figs. 4 and 5 show a thalsperre of the same perimeter, but built partly of dry masonry and partly of masonry in mortar.



The up-stream as well as the down-stream side, is built in arch-form, making a saving in the masonry of the wings. The masonry of the down-stream face is laid in mortar, as is likewise that of the crest and culvert; all the other parts are of dry masonry. The cost of such a thalsperre is by no means greater than that of those built entirely of dry masonry. This style has the advantage over the latter, having smaller dimensions and greater strength. Dry masonry alone should be used where the cost of

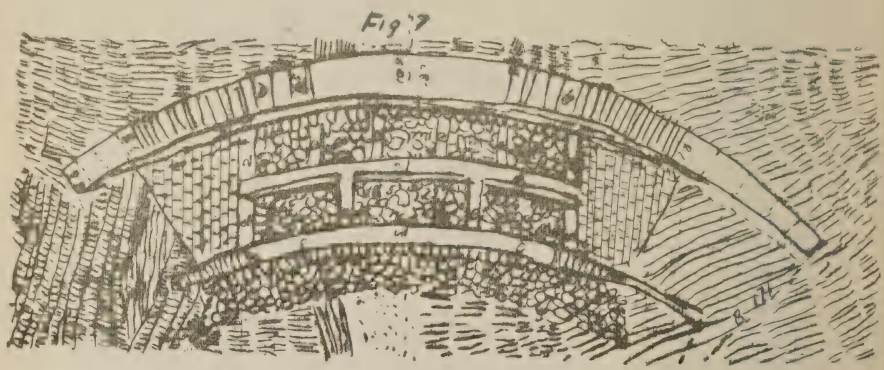


transportation of cement and sand is too high. In the main thalsperren only masonry laid in mortar alone should be employed, likewise where the shores are inclined to slide and slip and where the grade of the stream is too steep to permit a good footing for a dry masonry dam. In all other cases a combination of dry masonry and masonry in mortar—mixed masonry—shall be used.

The construction of the thalsperren varies according to local circumstances. Where the shores are liable to move they are built

straight, and where the bed is of little resistance, aprons and wings are added. In some cases counter-dams are built below the thalsperre, forming a basin or water-cushion, so that the water falling over it cannot injure the toe or apron. The foot should be protected with a good solid pavement, and this in turn with a row of piles, and its sides by hurdles.

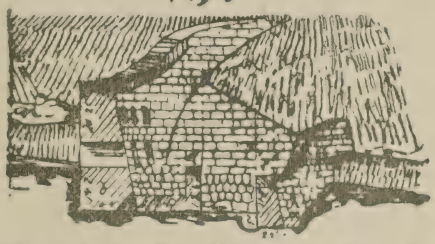
An interesting example of this kind is the thalsperre No. 1 of the torrent Riou-Bourdoux in the perimeter of St. Pons. This thalsperre forms the base of the whole system of improvement in this perimeter and is intended to raise the bed of the torrent for a distance of 4,000′, by a gradual increase in its height. (Fig. 6.)



Its dimensions are made unusually large. It is built entirely of masonry in mortar. It is 26.2′ high above the bed of the torrent, 274′ long (measured along the crest), and 10.5′ thick at the crest. The foundation is 14.9′ deep. In the lower part are five large

culverts, and in the upper part six, all of them provided with iron gratings. The apron was built with great precaution. Besides the counter-dam at its lowest edge, there is a parallel cross-dam in the apron, dividing it into two sections, half way between the thalsperre and the counter-dam. The section between the thalsperre and ring *a* (Fig. 7) rests upon a solid bed of masonry *f* (Fig. 8). It is divided by the walls *c* and *d*, parallel to the stream

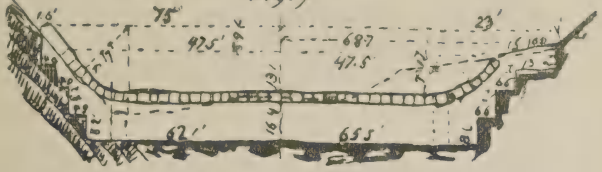
Fig. 8



and corresponding to the five discharge openings, into five sub-sections (*m*) while the lower section (between *a* and *c*) is divided similarly by the walls *d* and *e* into three sub-sections (*n*). The eight sub-sections are then paved with large rocks set on edge; the pavement in the sub-sections *m*, is at least even with the top of the ring *a*, but some of the rocks reach above the walls *e*, so that they may not be so directly attacked by the water. The pavement in *n*, is a little higher than the counter-dam *c*, but lower than the ring *a*. Below the counter-dam is an apron of stones 18′ thick. There are strong wings (*r r*) at 90° to the thalsperre on each side.

The crest of the thalsperre is level for 66′, concentrating the water in the centre of the same (Fig. 9). The water passing

Fig. 9



over the crest spreads on the apron below it, which has a width of 118′. This and the roughness of the pavement contribute greatly towards calming the water.

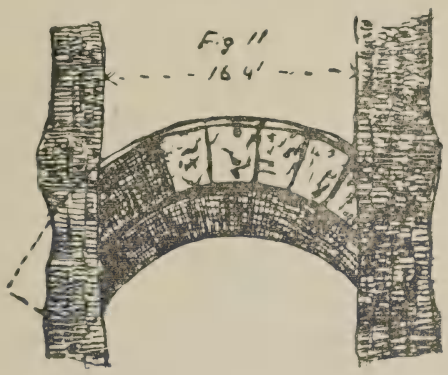
The crest of the wall *a*, offers a regular bed, and the water after falling 2′ more is perfectly quiet. The foundation of the counter-dam *c*, reaches 7′ below the stone—filling in front of it. There seems to be no possibility of ever destroying this carefully constructed thalsperre, especially since the apron has been built with the largest obtainable stones.

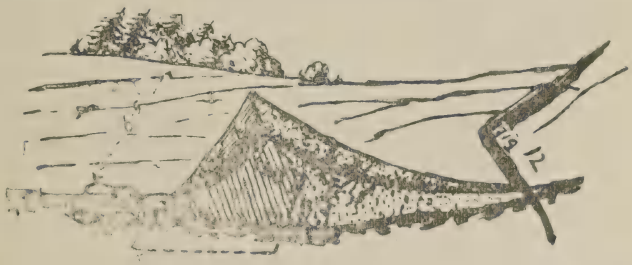
The total cost was $4,136.40. The itemized account was as follows:

Cut-stone.....	7413.	cubic feet	@	28.9	cents.
Ordinary rubble in mortar..	158,055.75	" "	@	11.5	"
Pavement.....	36,111.90	" "	@	4.7	"
Earth excavation	6754.63	" yards	@	19.8	"
Rock "	1187.15	" "	@	58.0	"
Concrete.....	67.91	" "	@	3.50	dollars.
Iron anchors.....	242.00	feet	@	74.5	cents.

The Pont-alto-Thalsperre in the gorge of Ferrina in the Tyrol (Austria) may be mentioned as a curiosity. It was first constructed in 1538, or 346 years ago. Above the thalsperre the gorge expands into a wide basin, while below it becomes narrower. It is 114.8′ high. The bed in front of it is 30′ lower, making the total fall 145′. This bed is compact Jurakalk, and is lowered about every year ¼″ (total erosion is in 346 years 5.91′) The sides of the gorge are of Jurakalk in the lower part, and of reddish marl-slate in the upper part. The length at the bottom is 14.75′, half way up 23′, and at the crest 32.8′. According to the old records, the thickness in the first 16.4′ of height is 6.54′, and in the succeeding 56′, 14 5′. The stones are of great weight. At the height of 56′ there is an arch, built to relieve the old lower part. The present thalsperre was commenced in 1751. It was built of dry masonry, single rocks weighing not less than 82 tons, some of them 163 tons, and were well laid and tied by iron rods. In 1824-25 it was entirely reconstructed. In 1850 it was raised to a height of 111.5′, and in 1883 to the present height of 114.8′. In this year it was thoroughly examined and found to be in good condition. How important this structure is, will be noticed by the fact that the river Fersina deposited behind the same 355,000 cubic yards in about two weeks during the high water of September and October, 1882.

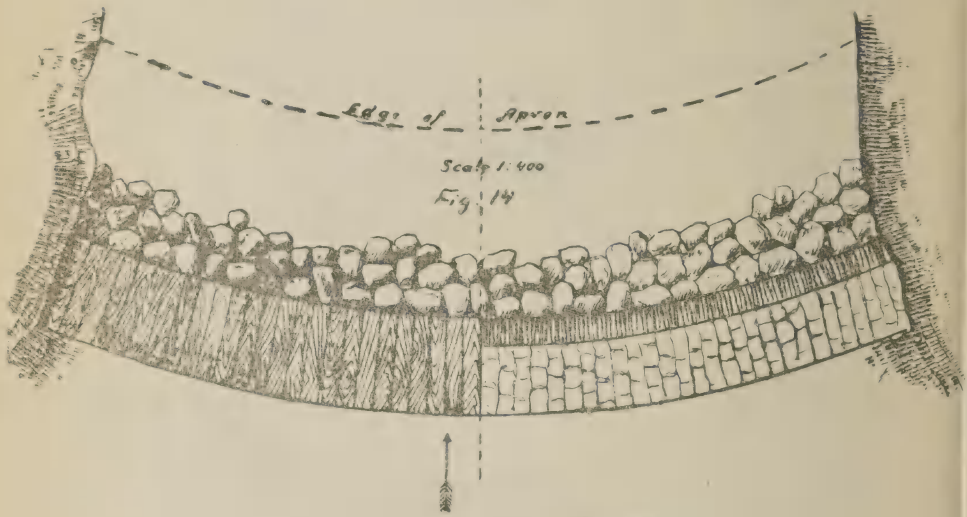
Figures 10, 11 and 12, represent an example of smaller thalsperren, used in Styria and Corinthia, in Austria. They are made of dry masonry. The sketches are sufficiently clear, so that no farther explanation is necessary.





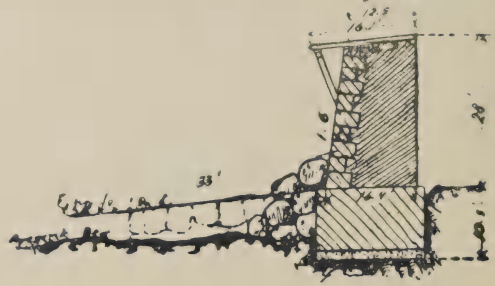
Thalsperren used in the river Gail in Austria, are shown in Figs. 13 and 14. Some of them are not built on bed-rock, but have a concrete foundation. The apron of one of them, made of loose rocks, sunk down into the bed during the high water

Fig. 13
Scale 1:400



Scale 1:400
Fig. 14

Fig. 15



in 1880. It was replaced in 1881 and secured by crib-work 26′ distant from the thalsperre.

The Osselitzen thalsperre (Figs. 13, 14 and 15) is the most important one in that district. The apron, made only of loose rocks, was soon carried away, but was replaced in the same manner, which will be continued until the bed rock is reached.

This thalsperre will store 42,000 cubic yards of detritus. It was built in 1877. In 1881 it was entirely filled up, an average quantity of 10,500 cubic yards having been deposited annually. This equally distributed over its water-shed gives a wash of but $\frac{1}{64}''$ per year.

Wooden Thalsperren.—Thalsperren built of timber are not desirable. The wood being alternately exposed to dryness and moisture soon rots, and the structures are frequently damaged by large bowlders brought down by the freshets. In the Canton of Berne, Switzerland, many thalsperren constructed of timber, have been cut in two by the friction of the sediment. Figs. 16 and 17 show wooden thalsperren used in the Tyrol.

Fig 16.

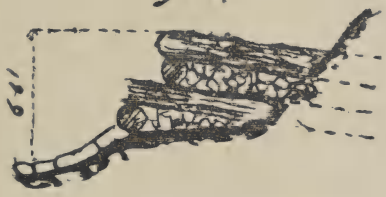
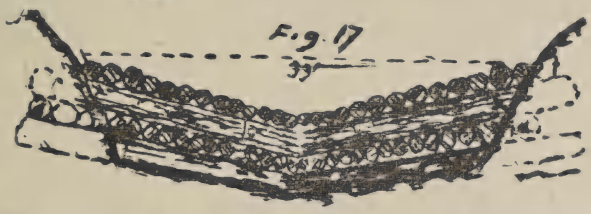


Fig. 17



They are built on two large sills which intersect each other at an angle of 130° to 140°. They are notched and bolted and laid securely into the bed and shores of the torrent. Timbers, varying in length from 3 to 15′, according to the distance to the next thalsperre, are laid lengthwise upon these sills, On these, other timbers are placed and secured with iron screw bolts. The

spaces are filled with gravel and small stones. An apron is placed below the structure.

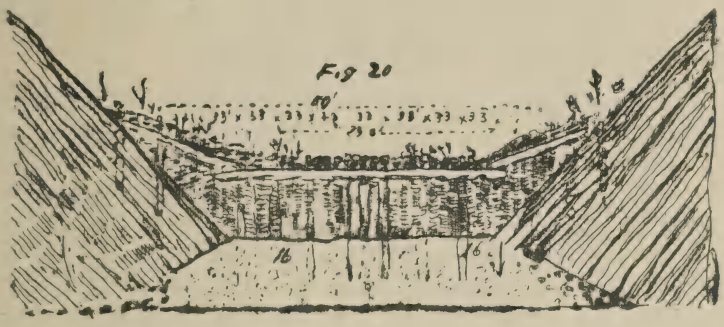
In other parts of Austria thalsperren are built of regular cribwork. When the space behind them is filled up, the surface of the detritus is paved.

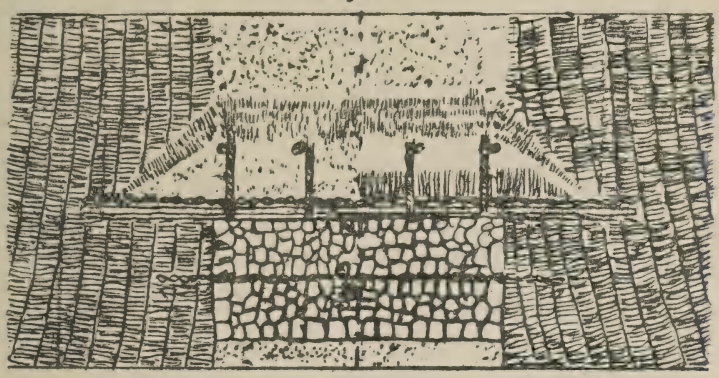
Figs. 18 and 19 show the wooden thalsperren in the Gail

river improvement (Austria). Their purpose is more to consolidate the bed of the ravine than to store debris.

Hurdles and Fascines.—In France, hurdles are used—first and second class. The latter are erected upon the fillings of the former. The hurdles of the first class are logs, and about 5′ high. The posts are connected with each other by a cross-timber. In the more important hurdles the cross timber is anchored to another row of posts (Figs. 20, 21 and 22). The hurdle being raised to a height of 1′, earth is filled in behind, and willow-slips are planted on it in close rows, so that their points reach 1.5 to 2″ beyond the edge. The hurdle is then raised 1′ and more earth filled in, and so continued until completed. Below the

hurdle a pavement is placed, which in the first class hurdles is secured by a secondary hurdle 1.5′ high, while in the second class, a simple row of posts are used. The second class hurdles are from 1.5′ to 2′ high.





After the filling in has taken place, a rough pavement is made for the water-course, and the rest of the fill is planted with trees. Where fascines are used, they are tied to posts of hard wood, driven

every 3′. Their ends are secured so that the water cannot run around them. After the first fascine has been laid, slips of willow or trees are spread out behind them, covered with earth to the height of the fascine, then another layer of slips is laid; a second fascine is put upon the first one, and the work is repeated until the desired height has been reached.

Drainage of Sliding Slopes.—Permeable ground resting upon impermeable sub-strata frequently slides after a rainfall. To prevent this, the rain water should not be allowed to percolate the ground, which has been accomplished successfully by means of drainage channels or ditches. In one instance in France four large ditches were excavated with a grade of 15′ in 100′, into which a number of secondary drain-ditches emptied. The main ditches were about 3.28′ deep and 2.2′ wide in the bottom. The bottom was well paved and the ditch then filled up, first with large stones, then with coarse gravel and finally with fine gravel. The secondary drains were constructed similarly; they were 2.3′ deep and 1.3′ wide in the bottom.

These drainage works have been very successful when used in time, and great expense saved thereby. They should be made as near as possible to the sources in the high mountains where slides have caused small depressions, and which are liable to retain large portions of the rainfall and snow. In the perimeter of Sanières the cost of such drains was:

Excavation	per	1	running	foot,	main ditches	7 cts.	secondary	ditches	2 cts.
Pavement	"	"	"	"	"	3 cts.	"	"	1.5 "
Filling	"	"	"	"	"	1.6 "	"	"	5.5 "
						11.6 cts.			9.0 cts.

Similar drainage ditches have been used extensively in Austria, and when constructed properly, have been always successful in preventing the formation of slides.

Protection of very Steep Slopes.—To secure and protect very steep slopes, a series of narrow horizontal berms with vertical slopes and the bottom inclined towards the mountain along the side hill (Fig. 23) are cut. A laborer places plants upon the berms *m*, *n*, so that their roots are about 4″ distant from the

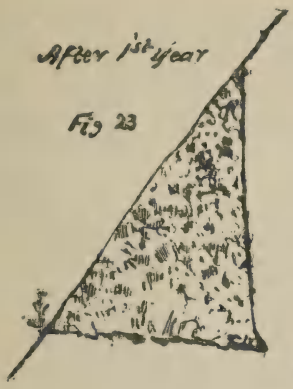


Fig 23

Fig 24

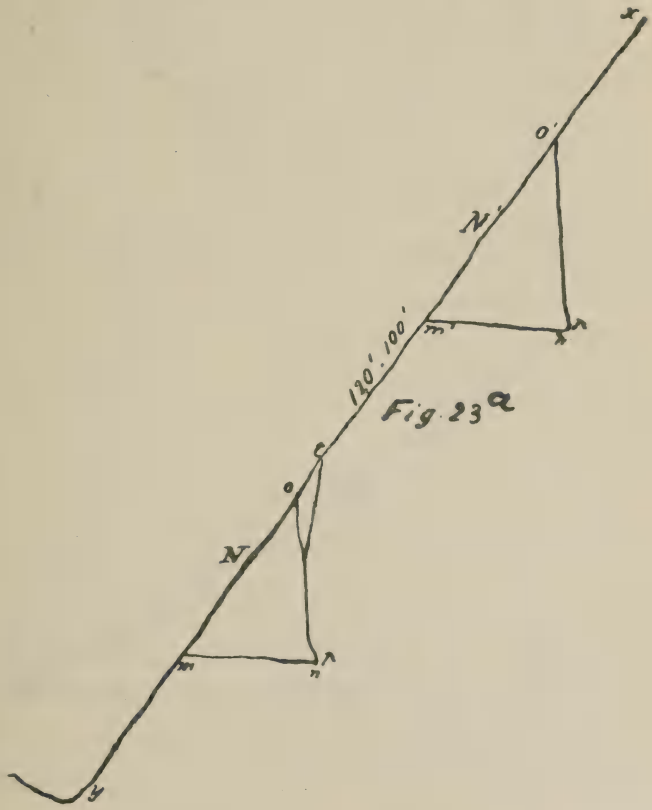
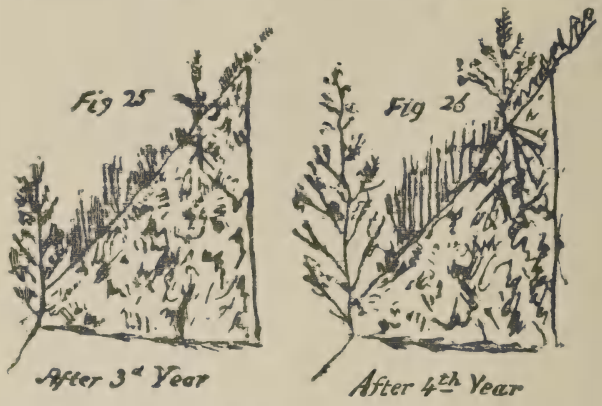
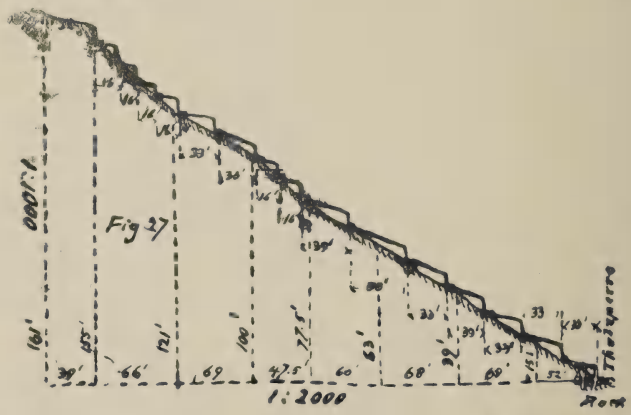


Fig. 23a

outer edge; he then covers them with a little earth, which he takes from the slope *o*, *t*. Another laborer prepares meanwhile the next higher berm and throws the dirt excavated upon the first berm until the same is completely filled. This operation is repeated until the entire slope is secured. After two or three

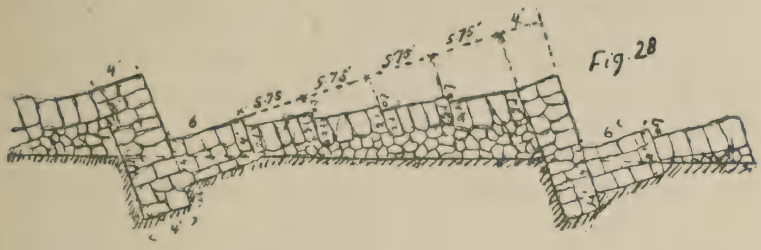


years the ground filled in is fit to be planted with fir trees. The ground between the fir trees is used for grazing (Fig. 23-26.) The cost of these berms, including planting, was 53 cents per 100 running feet.



Treatment of very steep parts of the Stream.—Where the grade of the torrent is too steep to allow the erection of regular thals-

perren, a construction was used which is shown in Figs. 27, 28 and 29. The work was of dry masonry, with the exception of



the lowest thalsperre, which formed the base of the whole system and was built in mortar. In the case illustrated, the original grade of 37′ in 100′ was by this means reduced to 11′ in 100′.

In those instances where one shore consisted of solid rock, and the other of loose material, spurs of dry masonry were built, by which the current was forced over to the solid rocky shore.

Description of the improvements of the perimeter of Faucon, Department des Basses-Alpes, France.*

The application of the above explained principles and constructions is best shown by an account of one of the most extensive and important perimeters in Southern France. Before the improvements were commenced, the country consisted of denuded hills and mountains and devastated valleys, crossed by deeply eroded watercourses. The devastation was caused by the unre-

* The word "perimeter" as here used means the area set aside for improvement, embracing all the tributaries of the particular torrent and all the lands needed for the intended work.

stricted cutting of trees, and by a continuous use of the ground for grazing, especially for goats and sheep—all vegetation was destroyed consequently. The result was, that the streams became very destructive, endangered the roads and villages, and destroyed the farms in the lower valleys. The county of Basses Alpes (in which this perimeter is situated) and that of Hautes Alpes furnished for a long time the largest number of emigrants of all France, who left there because the land had become so impoverished that it could not support them. But this condition of affairs has changed since the government commenced the work of improving the streams. There are still large denuded tracts and many dangerous torrents, yet large areas planted with trees and grass can be seen, not only around the sources of the torrents, but also on the slopes and side-hills along their entire length, thus protecting them permanently against meteorological influences. The once so dangerous torrents are now converted into harmless waters, assisting the farmer in increasing the yield of his fields.

The perimeter of Faucon embraces the watershed of the two large torrents, the Faucon and the Bourget, also the two fan-shaped erosions, Buriane and La Marquise. They are tributaries to the river Ubaye, and are located on the southern slope of the mountain range dividing this river and the Durance. The average elevation of this range is 9,200′ above sea level, with some points 9,850′ high. The valley is about 3,940′ above sea level. The slopes of the higher parts are very steep and abrupt. The rocks from the apex down to 6,240′ are tertiary slates (called flysh), belonging to the eocene formation. Below this is a layer of hard and homogeneous limestone, dividing the tertiary formation from the black marl of the secondary formation, which reaches to the valley. (See Fig. 30.)

The Bourget belongs to that class of torrential streams which derive their detritus from decomposition of the higher regions of its water-shed and only partly from undermining the shores and eroding its own bed. The study of it is therefore especially interesting to California. Its sources are 9,645′, and its junction with the Ubaye river is 3,850′ above the sea level; its total length is 16,800′ or nearly 3.25 miles; its average grade 1,792′ per mile;

the maximum grade is 2,855′ per mile, and the minimum 1,370′ per mile. The stream, a continuous line of falls and drops, has a solid bed. The two principal tributaries to this torrent are the Rata and Chasse-Lièvre. They are cut deeply into the black marl and assume at times formidable dimensions. Seventy years ago the Rata was a very insignificant rivulet, a few feet wide; in 1874, before the improvements were commenced, it was 260′ wide and 100′ deep. The stream Bourget was formerly a great danger to the town of Bourget, and to the villages and farms along its course. The government wagon road, No. 100, was frequently buried under the detritus of this stream, making traveling dangerous and at times impossible. The town of Barcelonette was also endangered by these two torrents, although situated above their junction with the Ubaye river, the detritus brought down by them raising the bed of the river very materially.

This state of affairs made the improvements absolutely necessary.

The area of the perimeter is 2,150 acres (previous to 1874, nearly altogether devastated), of which amount 1,891 acres are now under cultivation. The first work was the building of trails and roads, the erection of barracks for the laborers, and of storehouses. The construction of these roads is worthy of special mention; their first cost is amply repaid by the many advantages gained; the supervision of the work is facilitated and will therefore be more thorough. All the work can be done cheaper, and as the roads are located with a view to the advantageous working of the future forests, they are of permanent value. At the same time small areas of land were prepared and planted with fir and pine seed.

The watershed of the Bourget proper, is 818 acres.

In the higher regions horizontal berms, 6.55′ distant from each other horizontally, were cut out all along the slopes. Every 10′ holes, 19.7′ long and 16″ deep, were dug in the berms. The width of the berms was 1.64′ and their depth was 1.33′.

In this manner a large area of the perimeter was prepared in 1870. Simultaneously the work in the lower sections, where the black marl is predominant, had been commenced. It con-

sisted principally in the laying of numerous fascines, in the planting of pine and other trees, and the seeding of feed grass on the deposits of detritus and upon the shores.

Different varieties of trees were planted in different elevations. In 1870, a large thalsperre of dry masonry was erected at the highest point of the lower section, for the purpose of holding back all the large bowlders and to protect the lower works. At the same time all the necessary surveys and investigations were made, so that a thorough plan could be projected. Everything was carefully studied and determined.

The preliminary work occupied two years.

In 1872 the thalsperre, described on page 127, was built. Up to 1875, twenty thalsperren were built in the Bourget proper, and three in the Rata tributary, at a total cost of $21,501.40.

The prices paid were:

1 cubic foot of masonry of cut stone	28	cts.
1 " " " dressed rubble	19.8	"
1 " " common rubble	9.1	"
1 " " dry-masonry	3.7	"
1 cubic yard of excavation (earth and loose stone)	7.6	"
1 " " " " (rock requiring blasting)	30.0	"
Transportation in barrows maximum distance 82′	3.0	" pr c ft.
Trimming and dressing stones for crest and down-stream face	7.4	" pr sq. ft.

All these thalsperren have been filled up. In order to keep these fillings in their steep grades and to prevent any erosion, the water must be confined to a definite channel, its velocity diminished. To accomplish this, two parallel hurdles, 30–33′ distant from each other are put lengthwise on each filling; the shores on both sides are properly sloped, the material obtained thrown behind the hurdles, and slips of trees planted. Between the parallel hurdles a series of cross-hurdles 16.4′ distant from each other and 12″ to 20″ high are built so that a line connecting the centre of their crests corresponds to the grade of the fillings.

Whilst this work was progressing, the tributaries were improved by means of fascines and living thalsperren.

The result of all these improvements is, that the torrent Bourget, once so dangerous, is now converted into a harmless stream,

its water now runs clear and has become a blessing to its surroundings, instead of being a constant source of anxiety.

The improvements of the Faucon in this perimeter are not yet completed. The Faucon intersects the slate formation in elevations from 9,800′ to 6,230′; the shores and slopes are covered only in a few places with a thin layer of unproductive soil. Slides are of rare occurrence. Avalanches are very troublesome. Descending, the valley becomes wilder; the river runs through earth of black marl and through ground composed of all kinds and sizes of material. The steep slopes, sometimes as high as 260′, are bare of vegetation and are crossed by numerous secondary tributaries. The grade varies from 1,056′ to 2,112′ per mile. After every storm the water erodes the bed and causes landslides of $\frac{3}{4}$ of a mile in width.

The talus occupies an area of 436.6 acres, 148 acres of which can be cultivated; the remainder is good land, but is continually threatened and diminished by each storm. To the end of 1882, the following work had been completed in the perimeter of Faucon:

40 thalsperren of masonry in mortar of mixed masonry.
576 thalsperren of dry masonry.
2,311 facines } living thalsperren.
2,820 hurdles }
3,440 feet of hurdles, placed lengthwise.
7,500′ of covered drains.
14, 380′ of open drains.
27 miles of roads and trails.
7 block houses, and
1,380′ of fences.

The expense to that date, including the planting, of slips, trees and seeds, amounted to $129,716.20, segregated as follows:

Planting, 29 per cent.; thalsperren, facines and hurdles, 56 per cent.; building of roads, barracks and other sundry expenses, 15 per cent.

Results Obtained by these Improvements.—The local benefit derived from the improvement of the perimeter of Faucon are stated officially to be:

1. Regaining 222 acres of the talus for cultivation	$34,000
2. Permanent protection of the area of the talus, which is under cultivation	93,000
3. Protection of the villages Faucon and Bourget	70,000
4. Protection of the farms and 6 villages located along the course of the torrent	44,000
Total	$241,000

Independent of the benefits derived in reference to the river Ubaye (not being charged any more with detritus), the protection of the town of Barcelonette and of the government wagon road, also not taking into consideration the value of the new forests, occupying at present 1891 acres, the benefit obtained by the expense of $125,716.20 is nearly one-quarter of a million.

On the 13th of August, 1876, when most of the improvements of the torrent Bourget were completed, and those of the Faucon just commenced, a terrible rain storm lasting twenty-five minutes occurred. In the highest regions the rainfall was 1.57″, and in the lower ones 0.47″.* The Faucon discharged during the 60 minutes a mass of 315,600 cubic yards, containing 23.4 per cent. of water and 76.6 per cent. of detritus.

The Bourget at the same time did not carry down any debris, but the water rose only 17.7″, lasting four hours.

In the perimeter of Curusquet, in the same valley, 834 acres were brought under cultivation and secured permanently against the effects of freshets, etc., until the end of 1882, at an expense of $37,884. The farms in the lower valley doubled in value, and the government wagon road was protected permanently against damage.

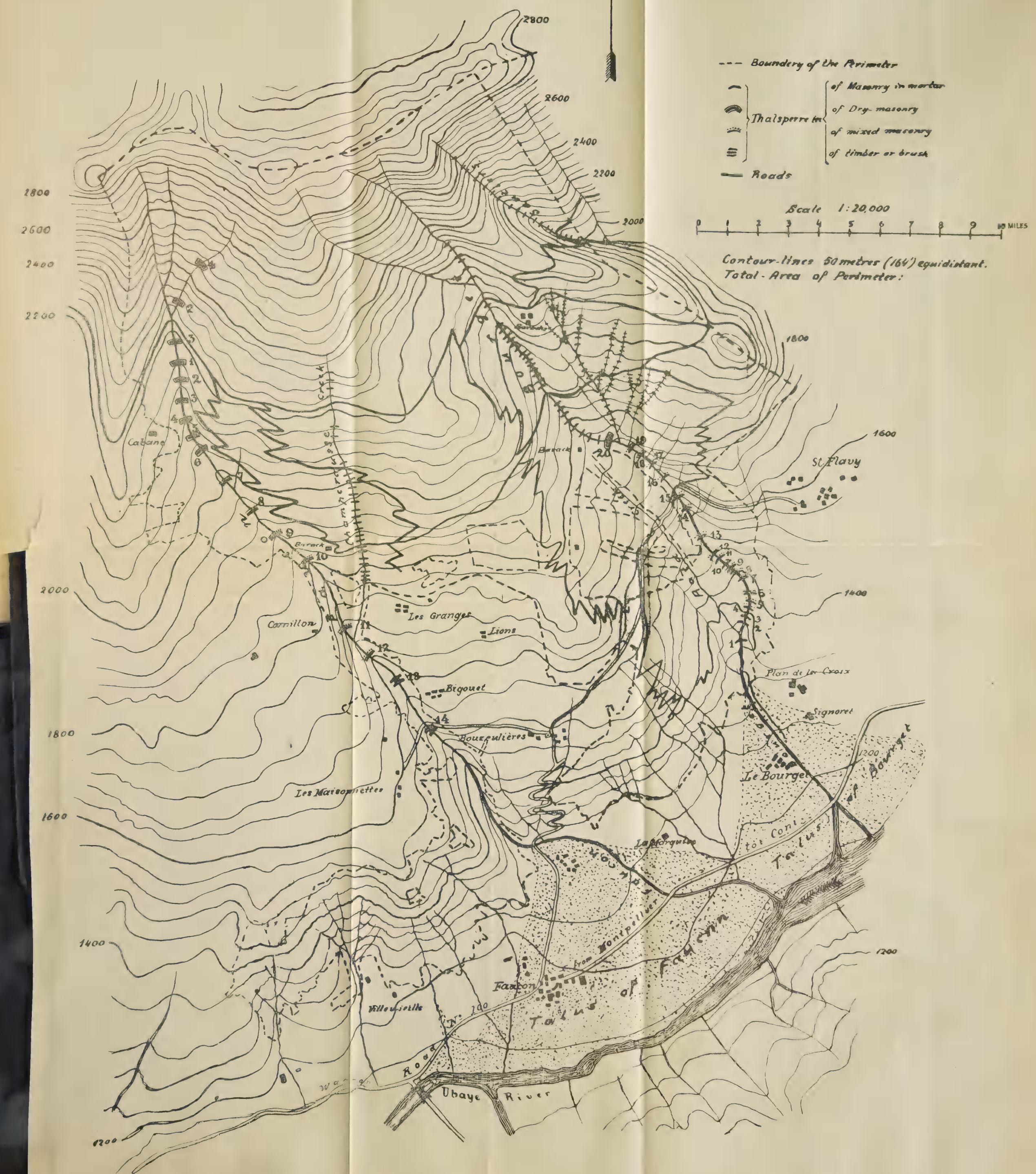
At an expense of $121,523, a benefit of $600,000 was obtained in the perimeter of Seyne.

These are only a few figures, but they are sufficient to convince even the most skeptical that, if the evil of sediment-carry-

*In order to ascertain the effect of the works carried out, three rain gauge stations were established at different elevations, dividing the area in three zones. The first zone was from 4260′ to 5580′, the second from 5580′ to 7540′, and the highest from 7540′ to 9884′. The necessity of this vertical division was shown by experience, which proved that the rain fall increases in direct proportion with the elevation. The gauge of the upper zone showed nearly double the rain fall of that of the lowest. Very careful observations were made after each storm. The water was measured when flowing over the crest of the Thalsperre No 2, after it was clear of detritus.

Perimeter of Faucon.

Fig. 30



ing torrential streams is attacked at its very sources, a comparatively small outlay will bring about large profits; provided however, that the necessary improvements are made after a carefully considered, well studied plan, and not on the base of a mere reconnaissance.

Damages done by Sediment-carrying Rivers in Europe.—A few instances of the consequences of floods in Europe may be of interest, as they will show that rivers, charged with sediment by natural sources only, can be formidable in their ravages.

In 1856, Southern France, especially the valley of the river Rhone, was visited by terrible high waters, which cost the lives of many people, and caused in an aggregate a damage of $40,000,000. The consequence of this calamity was, that the government took the matter of improving the torrents earnestly under consideration.

In the fall of 1882, five small communities in the valley of Fersina (Tyrol) lost $60,000 worth of land by two freshets covering it with detritus; besides this, whole villages were buried under the sediment, or partly carried away. Other communities in the same valley suffered losses to the extent of $210,000, while the city of Trient sustained damages aggregating $350,000. All this occurred in a few days.

The damages in the Alvisio valley (Tyrol) during the two high waters of September and October, 1882, aggregated about $300,000, of which $159,000 was by farms being covered with detritus or destroyed by the water, $84,000 by villages, saw mills and other buildings injured, and $57,000 by county bridges being swept away.

The same high waters did immense damage in the valleys of some tributaries to the Alvisio, amounting to over $300,000. The Brusago covered the lower valley with not less than 3,700,000 cubic yards of detritus, the deposit being over three miles long, from 170′ to 700′ wide, and 10′ to 20′ deep.

Several torrents already improved in that neighborhood sustained very little or no damages, which is a valuable proof of the benefits to be expected from the further improvements comtemplated.

The damages caused by the same high waters (1882) in the valley of the river Rienz and its tributaries, in Tyrol, amounted to $930,000. The Rienz alone carried away and deposited from eight to nine millions cubic yards of detritus. The quantity of water discharged during that period was 20,964 cubic feet per second.

The river Gail, a large tributary to the river Drau, in Austria, is at present being improved. The upper portion of the valley, called Lessach valley, has a length of 24.2 miles, with a total fall of 2640′, or a grade of 109′ per mile, a water-shed of 130 square miles; average annual rainfall (five years' observations) 52.2″. At its lower end is a large weir, called Wetzmann weir, 2340′ above the sea level. During the twelve days from September 12 to 23, 1882, 16 9″ of rain fell (maximum on September 16, 3.96″ per day). The amount of water flowing over the Wetzmann weir during the nine days from September 15 to 23, was 16,890,-867,014 cubic feet, or per second, 21,700 cubic feet. The amount of sediment suspended in one cubic foot of water was 1.74 lbs. (specific gravity 1.018.) In the nine days, 10,800,000 cubic yards of suspended sediment was carried over the weir, or 1,200,000 cubic yards per day. During three days between October 25 and 31, 1882, the rainfall was 2.6″, and the aggregate 7 8″.

Amount of water flowing over the weir,	3 days.....	5,620,000,000	cubic feet
" " " " " "	1 second.....	21,700	" "
" " sediment carried " " "	3 days.....	3,590,000	" yards
" " " " " " "	1 day.....	1,196,667	" "

In two tributaries of the Gail it was observed that rocks of 423.6 cubic feet (33 tons) were moved quite a distance down the river. The water was heavily charged with detritus, and its velocity was 16′ per second.

The damage during these two high waters to the fields of the Gail River valley only, amounted to $95,000, while the total damages were nearly $400,000. The damages by the same rains in the other valleys of the Drau amounted to $1,352,120.

The river Var, in the southern part of France, carried, in the year 1864–65, the total amount of 14,400,000 cubic yards of sediment into the Mediterranean Sea, besides 500,000 cubic yards of silt.

The Nile carries daily about 494,000 cubic yards of mud.

The river Inn, in Tyrol, carries annually 4,100,000 cubic yards of detritus.

The Elbe discharged in 1866, near Lobositz, in Bohemia, round 5,000,000,000 cubic yards of water, containing 1,280,000,000 cubic yards of sediment (1,070,000,000 cubic yards solid sediment and 210,000,000 cubic yards dissolved material).

The river Loire (France), above Bet-D'Allier, carried in an average of four years (1856-1859), 660,000 cubic yards of sediment per year, and below Bet-D'Allier 900,000 cubic yards (maximum, 1,650,000 cubic yards; minimum, 740,000 cubic yards). Including all its tributaries, the amount of sediment carried was 5,000,000 cubic yards per year. Sixty per cent. of this mass was gravel and sand.

Humphreys found the proportion between sediment and water carried by the Mississippi, to be (by weight), maximum, 1:670; minimum, 1:7152, and general average, 1:1321 (weight of cubic foot of water=436.247 grains troy).

In the Rhone, at Lyons, the proportions were (1844): 1:17000 by weight, and at Arles (the head of the delta) 1:7000 at low water, 1:230 in high water, and 1:2000 in an average. The greatest quantity ever observed was (by weight) $\frac{1}{45}$, the weight of the water being about two-thirds of its maximum.

FRENCH LAWS REFERRING TO MOUNTAIN STREAMS.

The first laws made in France, in reference to the improvement of torrential streams, are dated from July 28, 1860, amended June 8, 1864. Under these laws the Government granted subsidies to the amount of three million dollars for the execution of the necessary works. Both these laws were abandoned in 1882. The present law dates from the 4th of April, 1882. Its main points are:

1. The improvements can be done either by the Government, by private individuals, or by an association, with subsidy from the Government.

2. The "public benefit" of the projected improvements can be declared only by law.

3. The whole work must be done under the control and supervision of the Government, and after a plan worked out and approved by the same. All the needed ground must be purchased by the Government by agreement or by condemnation. The maintenance of the improvements is under Government supervision.

4. During the first twenty years no trees are allowed to be cut. The forests planted in course of these improvements are exempted from taxation for a period of thirty years.

5. Where a tract of land is not yet so badly denuded and devastated that immediate improvements are necessary, the same is "reserved" and cannot be used for pasture or agriculture for a period not exceeding 10 years. Should it be desirable to extend the time, the land must be bought by the Government.

6. When the improvements have been completed, the use of the improved land for pasturage is subject to certain regulations.

The execution of this law is under control of the Department of Forestry. At the head of the special branch of this department is at present the celebrated specialist P. Demontroy (*Chef du service de reboissement*). He is aided by one Chief-Assistant (*Inspecteur*), two Assistants (*Inspecteurs adjoints*) and two Clerks in the head office. The field work is done by parties of five to six persons each. At present there are eighteen such parties with sixty-three officers.

After the improvement works have been completed, and the new forests are old enough to be used for commercial purposes, the party is dissolved and the district is turned over to the General Department of Forestry or to the Department of Roads and Rivers. This organization has many advantages, the entire work being projected and carried out by one and the same officer. The officers of this service are educated at special schools.

To show the liberal appropriations made in France for public works, it may be mentioned that the Legislature of 1873 appropriated a sum of $166,500,000 for the improvement of the rivers and the extension of the canals. Of this sum $87,000,000 were to be used for improvement and maintenance, $57,000,000 for the construction of new canals, and the remainder for other work, to be expended during a number of years. This is the great ad-

Now what can we learn from the above statements in reference to our conditions here in California?

Two of the principal causes of the damaging high waters in Europe have been the inconsiderate destruction of forests and the unrestricted use of the mountains for pasturage of sheep and goats to the final extinction of all vegetation. Both the wood and lumber business, and the raising of sheep and goats, are important industries, upon which the inhabitants there largely depend, and which have been the first cause of settlement of these mountainous districts (similar to the gold mining in California). The continuous and unlimited prosecution of these two industries has finally become disastrous to the lower valleys by the immense masses of detritus carried down by the torrents—which became the more powerful the more the timber was cut and the more the mountains were used for pasturage—covering large areas of the best arable land, raising the bed of the rivers and thereby increasing the danger of floods. The government, being annually called upon for assistance by the damaged communities, began to study the causes of these devastations, and arrived at the conclusion that remedies applied to the very source of the evil only would secure permanent success. The forests were replanted and new ones started, the threatening slopes were secured and protected, and the grade of the torrents was changed to the grade of equalization. The use of the new and replanted forests and pastures for purposes of industries was not prohibited entirely, but was simply regulated and compelled to keep within certain limits.

This condition of affairs is somewhat similar to that in California, with the following facts in favor of this State: 1st, the grades of the mountain streams are comparatively gentle here and their beds wider than those before mentioned, and 2d, the devastation of the forests has not as yet attained such proportions as in Europe. It is popularly assumed that all the detritus flowing down the Sacramento and San Joaquin rivers alone

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vantage the European countries have over us, that appropriations for public works are made at once for the entire extent of the same, and not from year to year. There the designing engineers see their way clear ahead to the completion of the intended work, and can make their project and plans accordingly, after a thorough and well studied system.

comes from the hydraulic mines. Sufficient observations have not been made to establish the correct proportions of detritus, derived from the different sources, but the facts above related lead to the belief that here also a large amount of the sediment in the rivers is due to what is called "natural wash." The same forces which are at work in Europe to deteriorate the water courses, with all the injurious consequences, are also at work here. Trees are cut without restriction and none are ever replanted.*

Considering all these facts, it seems to the writer that a system similar to that of France could be adopted here. The State and General Governments should join in a very extensive and careful examination of the question, not only of hydraulic mining and the damages done thereby, but of all questions concerning the injuries done to the navigable rivers, and to the valleys above them, including the effects of the many improvements made in the lower Sacramento and San Joaquin valleys in the form of levees and other reclamation-works. These valuable swamp and overflowed lands cannot be reclaimed permanently by treating them as a separate division, but only as a part of the whole system. The improvements should commence in the mountains, and gradually be car-

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* The State Engineer estimates in his report of 1880, that in the year 1879 4,900,000 cubic yards of sediment in the Sacramento river were due to natural wash, and 13,200,000 to hydraulic mining. Col. Mendell, in his report to the Secretary of War, Jan. 26, 1882, says: "A comparison of artificial denudation in mining with that due to natural agencies, if it could be fully made, would be a profitable and interesting step in this investigation. Unfortunately, the data for the determination of natural denudation in the Sacramento basin do not exist." Then, after making a few deductions by analogy with the natural wash of the Mississippi and Po, Col. Mendell says on page 28 of the same report: "These general considerations are calculated to convey to the minds of those familiar with the natural circumstances of rivers as clear a conception of the magnitude of the problem as would be afforded by a study of its details. They explain the accumulations in the river beds, by making it evident that mining operations contribute more material per year than the floods of that year are able to carry. It also becomes plain that if the mining were to cease now, the flood being able to transport considerably more material than that due to natural erosion, would then be in a condition to attack deposits in the beds, which are comparatively safe so long as the floods are overloaded, as they now are." Mr. M. Manson says in his report to Col. Mendell (dated Jan. 5, 1882): "The natural or unavoidable wash from the basin of Feather river is great and the wholesale stripping of the fine timber districts and the unrestricted pasturage of large herds of stock renders this wash greater year by year."

ried down to the valleys.* The work should be carried out according to a well studied plan, based on absolutely reliable facts only. The investigation should not be restricted to a short time, because careful and detailed studies are necessary to success. Immediate results cannot be expected, as the question at issue is of such a nature that only time will prove the value of the improvements. The maintenance as well as the construction of the improvements must be under the supervision and control of engineers. The most important duty of the engineer, engaged in the treatment of rivers, commences when the works of improvement are finished and their effects can be studied. How far we are yet from being able to determine beforehand the effects of works of improvements in rivers, is demonstrated annually by the devastations of freshets and floods. The improvements should be made under joint control and supervision of the State—and General Governments. The necessary means should be raised by subsidies of both governments and by a special State tax. The latter seems to be justified, as the rivers are the arteries of the State, and as the permanent improvements of the rivers will increase the production, cheapen transportation of the farm products, and attract a large immigration, thereby raising the value of property over the whole State.

By carrying out some improvements similar to those in France, the hydraulic mines could be allowed to continue their work, they being restricted to a certain maximum of gravel to be washed annually. This maximum should be established from year to year by a commission, consisting of representatives of the respective districts and of the State and U. S. engineers in charge of this work, and be ascertained according to the amount of detritus, which can be stored by the additional improvements contemplated. The largest portion of these annual expenses (say 75 per cent.) should be borne by the mines, and the rest be contributed by the State and the United States. The restricted and limited working of the mines would be better also in that respect,

*It is only a deception to believe that a regulation can be successful, if one large restraining dam at the debouchment of the mountain stream, or at the mouth of the torrential tributaries, is built. Such will hardly be capable of retaining all the detritus for any length of time, and is a constantly threatening danger to the country below it.

that it would create a permanent industry, and contribute for a long time to the wealth of the State, instead of being worked with nearly feverish exertions for a few years only, leaving behind nothing but deserted and abandoned mining camps. A slowly but steadily increasing industry is certainly a better base to build a State, and a permanent and prosperous community on, than one which is prosecuted a few years with all the energy that men are capable of, and then dies after a short brilliant existence.

That such restrictive laws are constitutional and can be enforced is proven by the game laws. The various animals are protected by them, so that they may propagate themselves and continue to give food and enjoyment to the living and following generations. Why not protect man also, in his possessions by a similar restriction of an industry, which is liable to damage him if prosecuted without such, but if stopped entirely, seriously curtails the resources of our State?

An additional remedy to those employed in France, which could well be used here, is that of reservoirs, where a large amount of the rain water and of the melting snow could be stored, until the rivers below are capable of carrying it off without overflowing their banks. Their discharges should be regulated by the carrying capacity of the rivers. Such a system is now contemplated to be built at the headwaters of the Mississippi, the St Croix, Chippewa and Wisconsin rivers. President Whittemore, in his address to the annual convention of the American Society of Civil Engineers, held last month at Buffalo, says in reference to this project: "Should the experiment prove successful to the degree anticipated, it may then be of moment for us to determine how far any similar plan may be applied, not only for the purpose of aiding navigation, but in ameliorating the condition of those many portions of our country periodically subjected to destructive inundations, often attended, as recently, by the loss of many lives and millions of dollars in property."

The rivers of California require speedy improvement whether hydraulic mining is continued or not. The above statements will therefore be instructive in either case. The writer is not prepared to go into further details bearing upon this question—all he desires is to call the attention of the members of this So-

ciety to the above stated facts, and their profitable application to our State. A thorough discussion of this question, and eventually actions taken by the Society toward the proper legislation, would largely contribute to its solution.

EXPLANATION OF APPENDED SKETCHES.

Figure 31 represents the part of the Bourget between thalsperren Nos. 6 and 7, as improved by a series of secondary thalsperren. This section is 460′ long, and the foot of the upper thalsperren, No. 7, is 69.4′ above the foot of thalsperren No. 6. The average grade of the natural bed was 15.08′ in 100′. The total amount of detritus stored in this section is 25,000 cubic yards. Thalsperre No. 6 is 16.4′ high; during 1874–75 10,500 cubic yards were stored behind it. Then the secondary thalsperren a, b, c, d and e—each about 4′ high—were built; until fall 1876, 3,800 cubic yards were deposited behind them. The hurdles f, g, h, i and k—also 4′ high each—were then erected, the same stored 3,000 cubic yards up to the spring 1877. Then the hurdles l, m, n, o, p, q, r, s, t, u, v and w, ranging from 1.3′ to 3.3′ in height were built, and hurdle k was raised 1′. The deposits behind them up to the fall of 1877 aggregated 4,000 cubic yards. Then x, y, z, a′, b′ and c′ were constructed (from 1, 3, 4′ high) and t and i were raised 3 resp. 2-3′. 2,700 cubic yards were stored by them up to the spring of 1878. The last work done was the building of the hurdles d′, e′, f′ and g′ (1, 3, 4′ high) and the raising of a′ 1.64′. This additional work stored 1,000 cubic yards up to the fall of 1878. The rest of these works were not more than $1,500.

Sketch 32 represents a part of the perimeter of Curusquet. The rock in this district disintegrates rapidly when exposed to the air. The detritus is washed down by the rain and fresh rock-faces are exposed anew—supplying again a large amount of

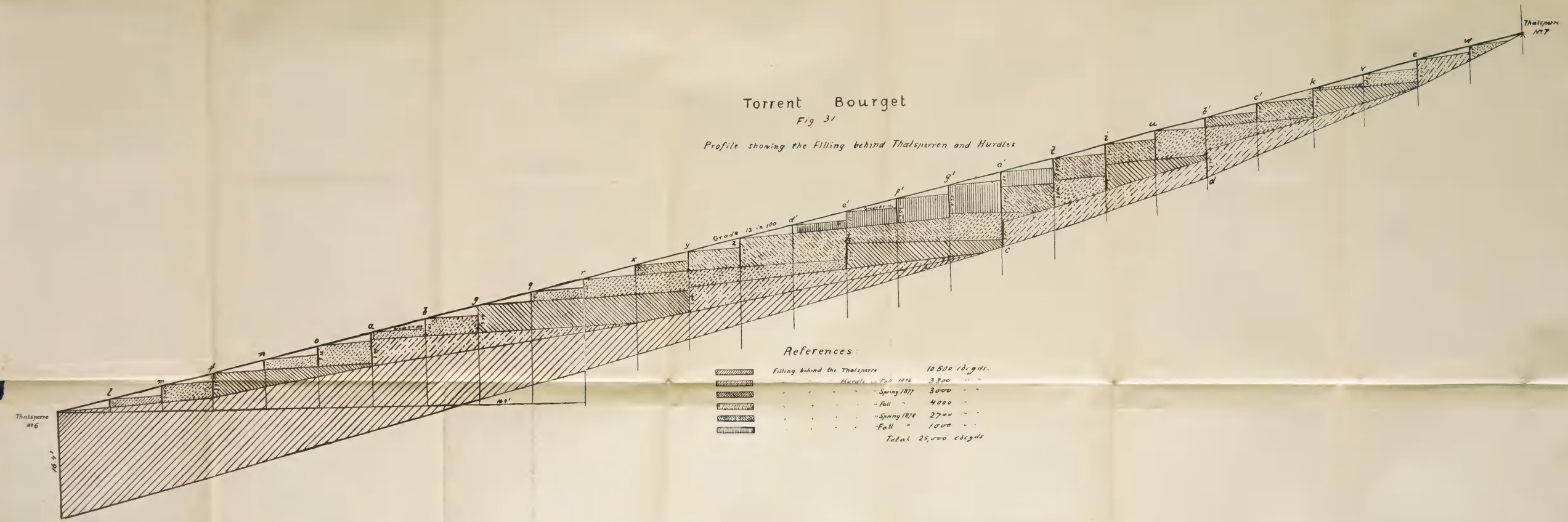
detritus. This is repeated over and over again. The following means were employed to prevent this: At the lower end of the erosions a strong hurdle was erected. Then all the irregularities of the surfaces, as for instance, sharp outcropping, were picked off as far as possible and the largest portion of the material so gained was thrown into the depressions, thereby raising their bed from 3 to 6 feet. The rest was used for the construction of small thalsperren from 1.5 to 2′ high; the spaces behind them were filled with material to the desired height. This new bed was then protected by fascines, made of green willows. The detritus lodged behind them soon became decomposed sufficiently so that trees could be planted. The loose material underneath permitted a good drainage.

Sketch 33 shows another portion of the same torrent and its improvement, accomplished partly by thalsperren of masonry and partly by live thalsperren.

Sketch 34 represents a portion of the torrent Bourget. The large thalsperre in front is the one illustrated in detail by Figures 2 and 3, pages 129, 130. Several other thalsperren are seen above. The fills are protected by fascines laid lengthwise and crosswise.

Sketch 35 represents a tributary to the Riou-Bourdoux. A large number of hurdle works is erected in all the erosions, the slopes are provided with horizontal berms, and trees are planted upon the latter.

V
C
2.4
5.9


Torrent Bourget
Fig 31
Profile showing the Filling behind Thalsperren and Hurdles
Thalsperre No 6
Thalsperre No 7
Grad^e 12 : in 100
References:
Filling behind the Thalsperre 10 500 cb.yds.
" " Hurdle " Fall 1876 3 900 " "
" " " " " Spring 1877 3000 " "
" " " " " Fall " 4000 " "
" " " " " Spring 1878 2700 " "
" " " " " Fall " 1000 " "
Total 25,000 cb.yds

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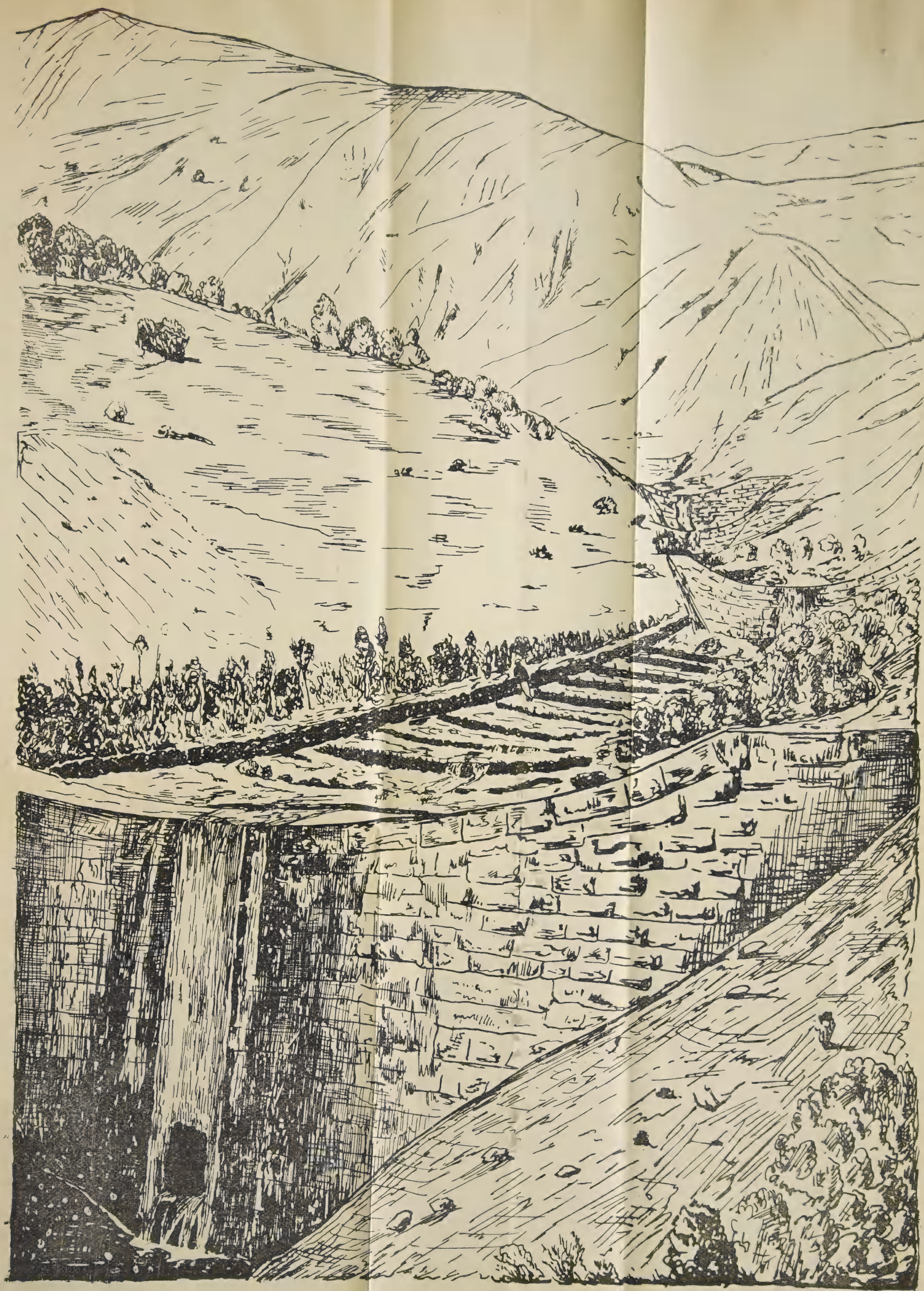
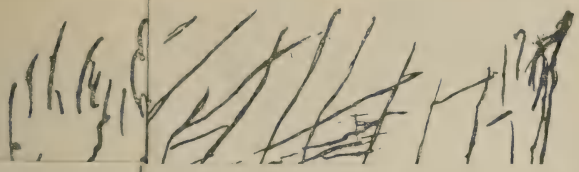
Sketch 32

Sketch 33



Sketch 34



Sketch 35

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

A CRITICISM OF BECKER'S THEORY OF FAULTING.

By ROSS E. BROWNE, M. Tech. Soc.

Read July 11, 1884.

See "Monographs of the U. S. Geological Survey, 1882."
Vol. III on the Comstock Lode, etc., by GEORGE F. BECKER.
Chapter IV on Structural Results of Faulting.

Mr. Becker says: "The evidence of faulting on the Comstock is manifold, etc." "Both to the east and west of the vein, too, the country rock shows a rude division into sheets, and along the partings between the plates evidences of movement are perceptible, decreasing in amount as the distance from the vein increases, according to some law not directly inferable." "Each sheet appears to have risen relatively to its eastern neighbor, and to have sunk as compared with the sheet adjoining it on the west. The consideration of a sheet or plate of rock under the influence of friction of a relatively opposite character on its two faces, therefore, forms the natural starting point for an examination of the observed conditions. It is shown in Chapter IV that if a country divided like the Comstock area into parallel sheets experiences a dislocation on one of the partings under a compressive strain equal at each parting, a vertical cross-section will show a surface line represented by two logarithmic equations."

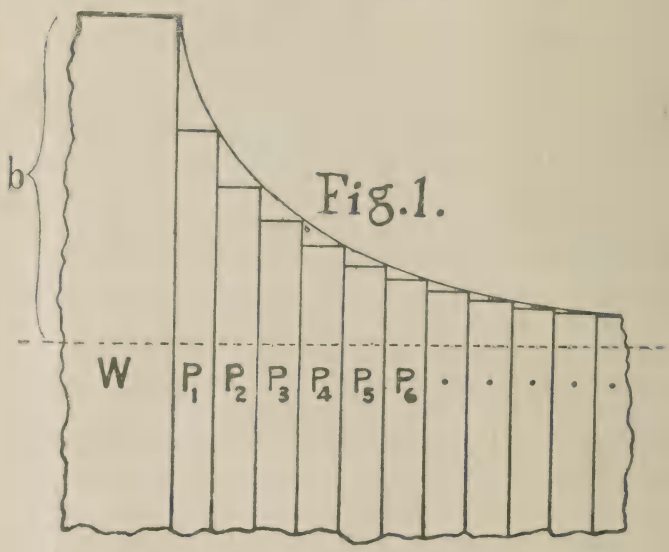
"Where a fault of the class under discussion has occurred, and where the resulting surface has not been obscured by deep erosion, the original surface can be reconstructed or calculated, and the amount of dislocation determined."

"The theory, though worked out independently of the Comstock, applies to it with much precision. Equations can be given representing very closely the surface line of a cross-section, the amount of the fault can be determined, etc."

The above quotations from the summary, pp. 376–380, are made in order to bring before the reader, as briefly as such means will permit, some of the prominent features of the theory which it is proposed to criticise.

In the discussion under the several headings, "Transmission of energy by friction," "Distribution of energy through a system of sheets," "The velocities of moving sheets, etc.," there appears a misconception of an important question involved.

Mr. Becker says if sheet W (see fig. 1) "begins its motion with a fixed quantity of energy, and if P_1 is fixed, the entire



energy will ultimately be expended in heat, sound, etc., on the contact. But if P is movable a portion of the energy of W will be communicated to P_1, etc." *

These statements are true, but it must be borne in mind that, in effect, the force of friction is simply a resistance to *relative*

*The pressure exerted by W upon P_1 was considered as uniformly distributed—see * page 163.

motion. If P_1 offers greater resistance to a relative movement of W than the body of sheets to the right offers to a relative movement of P_1, it follows that relative rest between W and P_1 will not be disturbed, and the latter will move with the full velocity of the former.** If P_1 is initially at rest, it will either remain at rest or acquire the full velocity of W.

"If P_1 is in contact with a third plate or sheet P_2 the energy received by P_1 will be expended wholly or in part in overcoming the resistance on the contact P_1 P_2." It should be kept in view that if P_2 moves at all, it does so with the full velocity of P_1, for the reasons above given. "If these sheets are the earlier members of a series of sheets W, P_1, P_2, P_3, ... , of indefinite number, then each sheet which moves will communicate a certain amount of energy to the next, and since the resistance of friction* is proportional to the distance through which it acts, each sheet which receives energy from its predecessor must move."

In other words, each such sheet must be translated. Herein lies the misconception. If the resistance, which a given sheet P_5 offers to motion, is greater than the resistance it causes to the motion of its predecessor P_4, it will remain at rest; and though it receives energy from its predecessor this energy is in the form of heat and will not cause translation of P_5.

Now follows this statement: "Since the sheets are in all respects alike and the pressure at each contact is the same, the frictional resistance or negative force at each contact will also be the same, etc."

This is an astonishing condition to impose, as it could never be realized (not even with carefully prepared sheets of paper), and to say that it could be realized approximately would but

**This statement apparently calls for some qualification, for if a considerable velocity is suddenly imparted to W, and the resistance mentioned means simply frictional resistance, the inertia of P_1 will give rise to a dislocation at contact W P_1. However, if the most reasonable conditions are imposed—if the acceleration of W is supposed to be small, and there is assumed to be a material difference between the frictional resistance which P_1 offers to motion of W and that which the body of the sheet to the right offers to motion of P_1—it is proper to consider that the resistance which the *mass* of P_1 offers to motion will not cause dislocation, but will result in vibrations in the elastic sheets transmitted through the projections at the contact. It is not supposed that it was Mr. Becker's intention to consider any appreciable velocity as being suddenly acquired. The "fixed quantity of energy," with which W *begins* its motion, cannot be energy of motion (kinetic energy).

* Probably "work of friction" is meant.

show a misunderstanding of the problem. Any small difference between the surfaces of contact, of a nature to influence friction, would change the character of the problem. There would be one contact where the frictional resistance would be less than at the other contacts and here only would there occur a dislocation. If the condition should nevertheless be entertained, there would, owing to the inertia of P_1, result a dislocation at the first contact W P_1. The sheets P_1, P_2, P_3, ... , would all remain at rest, though in unstable equilibrium.

In the real question at issue, then, if the contact between P_4 and P_5 offers less resistance than the other contacts, motion of W will simply produce the effect shown in fig. 2, and not the effect claimed by Mr. Becker and shown in fig. 1.

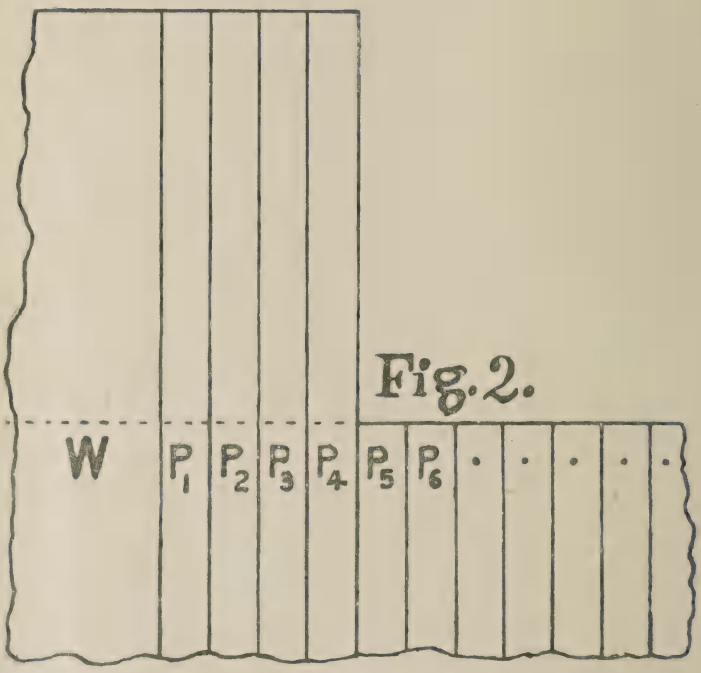


Fig. 2.

It would be purposeless to follow the mathemathical developments erratically based upon this misconception of the main question involved. Suffice it to say that a logarithmic equation

is reached to represent the supposed curve. However, some comment upon the "experimental verification" will not be out of place. Under this heading the author says:

"If the various assumptions made are correct, a fault under "certain conditions will result in a surface, a vertical section of "which at right angles to the strike of the fault will present a "logarithmic curve. Before proceeding to any further deduc- "tions, it is evidently desirable to test the correctness of the "postulates experimentally. I have supposed the sheets of "rock of infinite size as compared with their exposed margins, "because on this supposition the pressure per unit of area of "each parting will be the same.* If the plates were thoroughly "flexible, and if the pressure were applied on a limited zone "parallel to the croppings and removed by a distance greater "than *b* from either end of the plates, then the pressure ex- "erted on each plate would be the same, and would be dis- "tributed over an equal area, and the resulting curve would "still answer to the general formula deduced.** These condi- "tions we can approximately reproduce. If a pile of, say, one "hundred slips of very thin, flexible and uniform paper, eight "or ten inches long, with sharply cut edges, are laid upon a "flat surface, and a narrow weight of three or four pounds is "placed across them, the pressure under the weight may be "considered as constant. In the experiments I have made, the "weight employed was about 5000 times as great as that of a "single slip. If a blunt edge, such as that of a ruler,§ be now "applied at right angles to the longer dimension of the "slips, close to the weight, with a light pressure, and be drawn "away from the weight the fraction of an inch, a slight relative

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*See foot note page 160.

**If it is meant that the pressure per unit of area of each parting would be the same, the first sheet should have been made absolutely rigid, and not "thoroughly flexible," in order to justify this conclusion. The present writer commits himself to the opinion that if the sheets are flexible, and the pressure applied to a limited zone, the pressure per unit of area will rapidly diminish as the normal distance from the "limited zone" increases. See page 167.

§ The pressure under the weight might be considered as approximately constant and even as distributed approximately over the same area at each parting; but not so with the pressure under the blunt edged ruler.

"movement will be perceptible. If this application of energy "to the system be repeated a score of times, the ends of the pile "of slips will be found to form a curved surface instead of a "plane. If the frictional resistance is proportional to the pres- "sure, this curve must sensibly coincide with that given by the "equation

$$y = \frac{A\,m^{-x}}{1 + x\,t},\text{" etc.}$$

If the above directions are followed, the pressure applied with the ruler being made sufficient, a curve will be produced; but it is significant that a blunt edged tool is used for the purpose. If "the pressure per unit of area of each parting" is to be even approximately the same throughout each parting, why not distribute the weight uniformly over the upper slip, fasten it to the same, and move the weight? By proceeding in such a manner the result will be simply that illustrated in fig. 2.

Mr. Becker's experiment in no sense "forms a check upon the theory," since it deals with fundamentally different conditions. The fact is, the formation of this curve, in the experiment described, is due mainly to the *inequality* of the "pressure per unit of area" at the different partings

An explanation of the formation of this curve is of little interest to the general reader; but an attempt at such will be added in order to bring out more clearly the inapplicability of the experiment to the real question at issue.

There are to be found in this Chapter IV many such headings: "Logarithmic distribution of energy," "Equation referred to the cropping as origin," "Spacing of contours," "Evidence furnished by observation," "Topography chiefly due to faulting,"* "Dynamical theory of sheets," "Rules applicable to prospecting in uneroded districts," "Application of theory to landslips." The subject matter under these headings is replete with deductions and applications, many of which might well be questioned even if the theory were correct. The present writer doubts, for instance, the existence of the conditions essential to any real significance in the application of the logarithmic curves to the Sutro Tunnel section. The fact that a carefully selected section of a natural surface may be approximately covered with

* Referring to the Comstock country.

portions of such curves, when calculated by the method adopted, is of little import. Doubtless many other simple curves might have proved equally serviceable. However, this question will not be discussed at present.

An Explanation of the Formation of the Curve in the Experiment with the Slips of Paper.—A B (fig. 3) represents an elastic sheet

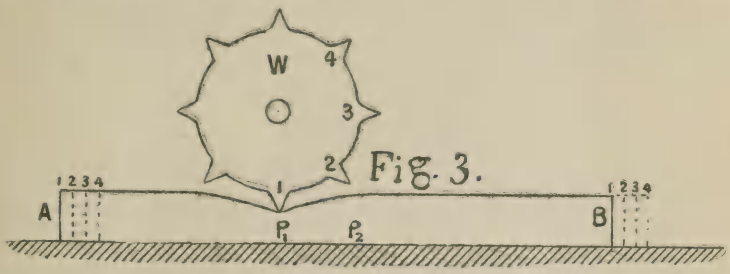


Fig. 3.

resting upon an incompressible base, and W a toothed cylinder. There is frictional resistance to relative motion at the contact between sheet and base. If a pressure normal to the surface of the sheet is applied through W, tooth 1 will compress the sheet at point P_1, as shown, and extend it in length. If now the cylinder is rolled toward B until tooth 2 comes in contact with and compresses the sheet, the part P_1 B will be further elongated. Since the pressure, and consequently the frictional resistance to motion, at point P_1 of contact between sheet and base, is great as compared with the resistance at other points of the contact, the translation caused by this elongation will be almost wholly in the part P_1 B of the sheet. If the cylinder is rolled still further until tooth 1 leaves the surface of the sheet, the part A P_2 will have contracted. After teeth 2, 3, 4, etc. have done their work, the accumulated effect will be a material translation of the sheet in the direction of rolling.

It is easy to see that a result the same in character will be effected if there is substituted for the toothed cylinder, a cylinder without teeth, the operation being continuous.

If an edged ruler is applied and drawn from P_1 toward B the effect will depend upon the magnitude of the resistance which the sheet offers to the relative motion of the edge of the ruler. If the edge be sharp and this resistance greater than the frictional

resistance between sheet and base, the result will be relative rest of sheet and edge and slipping of the sheet upon the base. If on the other hand, the edge be blunt and this resistance less than the frictional resistance between sheet and base, the ruler will slip on the surface of the sheet carrying the depression with it, and it is easily seen that the result will be the same in character as in the case of the rolling cylinder.

In rolling the cylinder from A to B the entire sheet will be compressed to thickness t_1 (see fig. 4), and the total translation

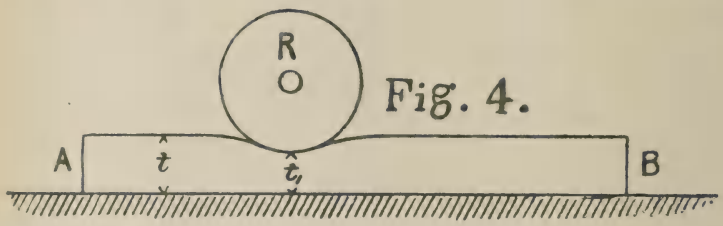


Fig. 4.

of the sheet will be approximately equal to the full amount of extension which would result from distributing uniformly from A toward B weights of sufficient magnitude to reduce the entire sheet to thickness t_1.

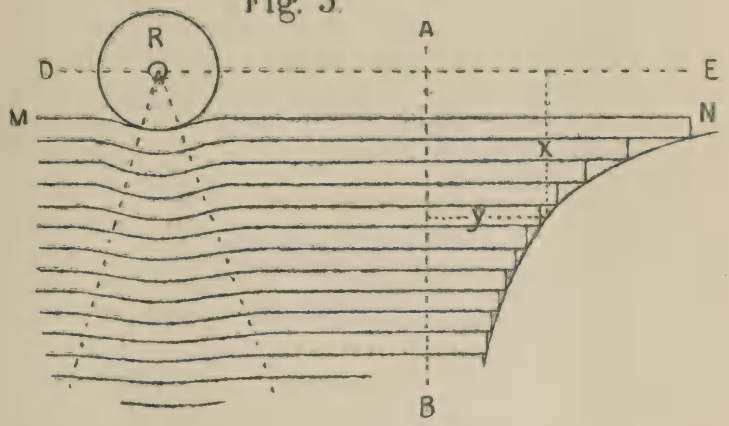
In explaining the formation of the curved surface the weight used by Mr. Becker will be omitted, as it only serves to keep the sheets in contact. The cylinder will be substituted for the blunt edged ruler. It will scarcely be doubted that these changes are admissible and will not affect the general character of the curve formed. They are made in order to simplify the statements.

Let fig. 5 represent an indefinite number of highly elastic and flexible sheets of paper, having their edges originally in the surface A B normal to the upper surface M N. If cylinder R* is applied with pressure to the surface M N, this pressure will be transmitted normally to the curve of depression formed. The area of surface over which this pressure is distributed will rapidly increase—hence the diminution in thickness of a sheet, due to compression, will decrease—with increase of the distance from the upper surface M N. If now the cylinder is rolled to

* Let the length of the cylinder be greater than the width of the sheets, and let it be so placed that its axis is normal to the longer dimension of the sheets.

the right the amount of the translation of a sheet will decrease with increase of its distance from the upper surface M N, and thus the edges will form a curved surface.

Fig. 5.



If it is important to show approximately the character of the curve, an equation is easily deduced after making certain assumptions. Let it be assumed:

1st. That the diminution in thickness at a given point of the sheet, due to compression, is proportional to the applied normal force per unit of surface where applied.

2d. That the extension in the length of a sheet, when uniformly loaded, is proportional to its diminution in thickness.

3d. That the pressure is uniformly distributed at any contact, over an area which is directly proportional to the distance x from the center of curvature of the contact surface between the cylinder and the upper sheet.

It will follow then, if c and C are constants and p represents the pressure per unit of area, that $p = \frac{c}{x}$ and since y is proportional to p, $y = \frac{C}{x}$.

The curve then will approximate in character an equilateral hyperbola, having A B and D E for asymptotes.

It is only claimed that the assumptions made are near enough to the truth to lead to a reasonably good conception of the character of the curve formed.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

ON RETORTING SILVER AMALGAM IN VACUO.

By F. GUTZKOW, M. Tech. Soc.

Read July 11, 1884.

About fourteen years ago, on May 31, 1870, I obtained a patent for an improvement in distilling "in vacuo;" that is, under diminished atmospheric pressure. The novelty was the application of a steam jet and certain pipe connections for producing the vacuum. At present, when the steam jet is frequently used for a similar purpose, there would be nothing particularly new in that. At that time, however, the modification in the construction of the Giffard injector, which enables to produce a vacuum in a closed vessel, was less known, and little, or not at all, practically applied. The process was intended for distilling alcohol. For certain reasons, I never endeavored to introduce it for that purpose.

In August, 1873, however, I published a paper in the *Mining and Scientific Press*, recommending the principle for the retorting of amalgam. I had in view to retort at a much lower temperature than usually required; avoid the leakage of quicksilver fumes, and in the case of very coppery amalgam, to draw, after the distillation was finished, a current of air through the hot contents. Reasoning that the lower temperature would leave the metal in a more porous condition, I wanted to oxidize a portion of the copper, and, after treatment with acid, obtain a higher grade bullion.

Although nothing further was done in the matter, I always thought well enough of my proposition to feel quite complimented, when, last year, a distinguished metallurgist, Mr. C. A. Stetefeldt, of New York, took out a patent on the identical idea of distilling in vacuo, by attaching a steam jet to an amalgam-retort. As far as any claims of my own were concerned, I wanted to let them rest, and hoped that Mr. Stetefeldt, when he introduced his patent at the Lexington Mill, in Montana, last year, would make a success of it. I am informed that he did not; nor was I astonished when I obtained a sketch of his ap-

paratus, which I consider faulty in principle. This circumstance tempts me to try to save a correct idea by publishing my own views how it ought to be put in practice.

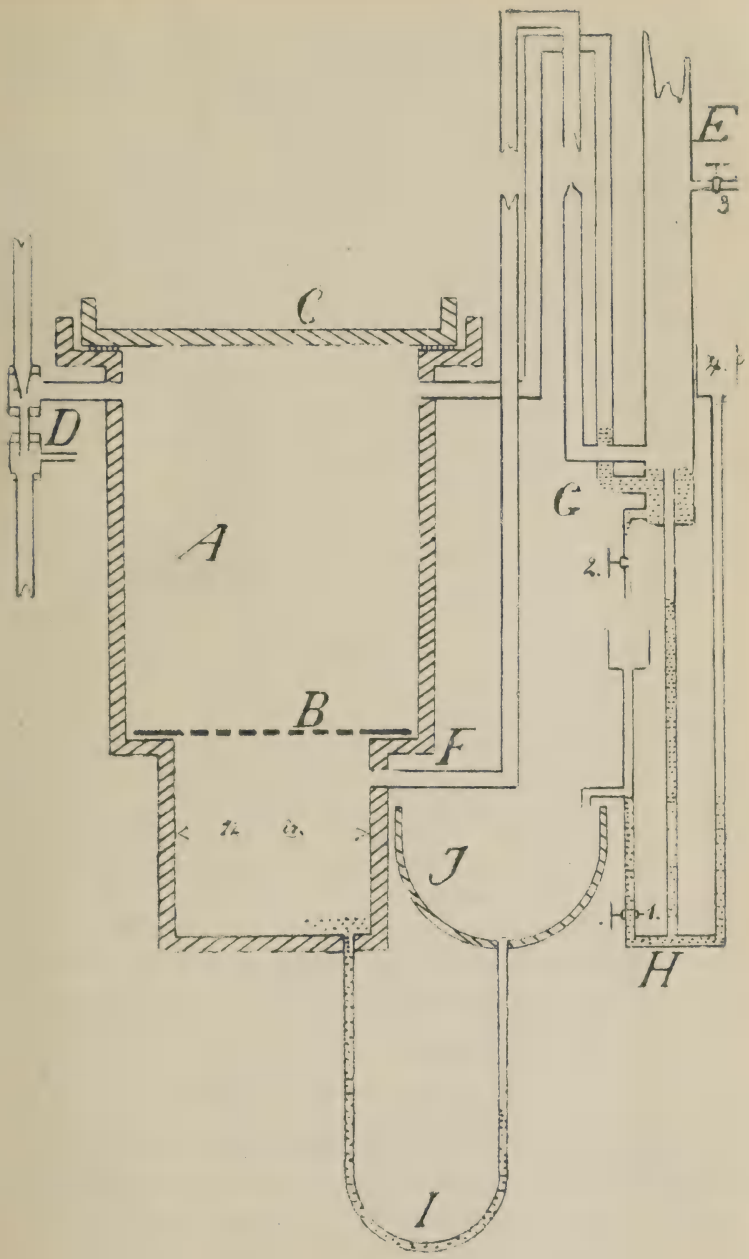
Mr. Stetefeldt blows his steam jet into the 3-inch pipe connecting with the retort, and carries the mixture of steam and quicksilver fumes through a closed sheet-iron box 1 foot wide, 2 feet high and 4 feet long, which is placed in a water trough. The condensing surface is increased by seventy-two horizontal 1½-inch tubes, secured like boiler tubes, and three vertical partitions force the gaseous current to a curved motion. Thus he obtains only a draft, but nothing approaching a vacuum, and the condensation of the mixture of steam and quicksilver fumes must be very ineffectual. Besides, the plant has an abundance of joints and chances for leakage—certainly out of place in a vessel which has to hold quicksilver and withstand the atmospheric pressure.

My own apparatus is represented by the figure in vertical section. It is somewhat similar to another constructed by me some years ago for a different purpose at a gold refinery in this city, which has been described in Percy's "Metallurgy, Gold and Silver," page 484.

A cast-iron tank, A, three feet high, two feet wide and as long as necessary to take in all the retorts of the establishment, is placed in the rear of the retorting furnace in right angle to the retorts. A set-off in the casting supports the sheet-iron, perforated false bottom, B, and a rim or shoulder, extending round the whole tank, carries the cast-iron cover, C. This cover, C, rests on strips of sheet-rubber which, when the air in A is exhausted, and the weight of the atmosphere, amounting to many tons, settles on the cover, is sufficiently compressed to form an absolutely tight packing. The vacuum is produced by the steam jet pump, D, according to well-known principles. The orifice of the jet is one-quarter of an inch and the steam blows, at the distance of one-half inch, into a half-inch pipe three inches long. From the latter the mixture of steam and air expands into a larger pipe, sucking up more or less air from a branch pipe, as shown in the figure, so that when the steam is shut off the vacuum in A is at once brought in communica-

tion with the atmosphere. Under a pressure of sixty pounds steam a vacuum corresponding to a column of eighteen inches quicksilver is readily obtained. A much higher vacuum can be produced by certain modifications which I will pass here, as I consider a vacuum of the stated tension quite sufficient for the purpose.

The tank, A, is filled with water to within one foot above the false bottom, the pipes for letting water in or out being omitted in the figure. The pipe, E, connects with the retort. The quicksilver vapor is led from the retort and condensed by a Liebig's cooler in the usual way, so that all the quicksilver thus condensed must flow into E. As long as the retort is not yet hot enough, the air escapes through G. When the quicksilver commences to run stopcock 2 is shut, the condensed quicksilver closes G, steam is turned on, a vacuum produced above the water in A, and the air or vapor in the retort forced to travel through pipe, F, the false bottom and the water, before reaching their outlet. The water in A need hardly to be renewed during one operation, as it will not get very warm. By far the largest portion of the quicksilver is condensed by the Liebig cooler, and what passes in to E, is cooled already. Besides, the latent heat of quicksilver-vapor is very small, only about one-tenth of that of water-vapor. If the Liebig cooler is made long enough, and constructed after correct principles, that is, in sections of gas-pipe with gradually reduced diameter, the water in the tank A may be altogether dispensed with. In any case, the condensing water in A, must not be allowed to run to waste before it has passed some other vessel where any suspended globules of quicksilver get a chance to settle. If the steam from the steam jet discharges into the same vessel the settling will be greatly facilitated by the heat. Where the mill-site allows it this settling vessel ought to be placed about twenty feet below A, otherwise a small Giffard injector must overcome the atmospheric pressure whilst the water discharges from A, during the distilling operation. Small as this inconvenience is, it is better altogether avoided as described above, by bestowing some attention to the construction of the Liebig cooler. The present style of sticking a three-inch pipe into another four inches wide and four feet


E
C
D
A
G
B
F
J
H
I

long is not sufficient to dispense with the additional water condensation, as described, when the speed with which the vapor rushes into the vacuum is considered.

It remains to mention two difficulties: In the first place, there will be required an automatically acting, absolutely safe contrivance which prevents the water from rising into the retort if the vacuum should be suddenly destroyed by leakage or or breakage before the workman can open aircock, 3. This is effected by the pipe, G, which connects the air-space in A, with the quicksilver at the bottom of E. During regular working the quicksilver will rise in this pipe correspondingly to the hydraulic hindrances of the false bottom and the cooling water. When the vacuum in A is destroyed, the quicksilver in G will fall back and allow the air to enter E.

In the second place, it is necessary that the workman can watch the flow of the condensed quicksilver at any time without using stop-cocks or peeping through glass tubes. This purpose is served by the combination of the pipes H and I, and the well, J, with the pipe, E, and the tank, A. The well, J, which also allows to ladle the quicksilver from A, when desirable to do so, receives the condensed quicksilver from E, and discharges it into A. If there is no vacuum in A, this is done by ordinary gravity; if a vacuum exists of, say, eighteen inches of quicksilver, the quicksilver in H will stand eighteen inches above its outlet; the well, J, will run empty and the atmospheric pressure will balance a column of quicksilver standing eighteen inches high in the left branch of the pipe, I. It will be readily understood now, how the flow of quicksilver into H, from E, will cause its discharge into the well, whilst the flow from the well into I, will cause its lifting into A. The level of the quicksilver in the right-hand branch of I, during the distillation below its level in the well previous to the action of the steam jet serves also as a vacuum-gauge to the workman. Under ordinary atmospheric pressure the weight of the water column in A, will cause the rise of the quicksilver in the well by one inch, more or less, but no water can, of course, escape. By closing stopcock, 1, and ladling quicksilver into 4, until it stands in

the funnel, the pipes, F, and G, are converted into barometers and that particular retort is disconnected from the vacuum.

The principal advantages of the described improvement are the prevention of loss of quicksilver and of danger of salivation by leaks in the retort door and the saving in time and fuel by the rapid removal of the quicksilver-vapor. For no other substance subjected to evaporation or distillation is the rapid removal of its vapor so necessary as for quicksilver. To compare the distillation as proposed and the one now practiced with the evaporation in the vacuum pan of a sugar refinery and in a closed steam boiler, would still not be sufficient to cover the case. Quicksilver vapor has not, like steam, a tension rapidly increasing with a slight rise of temperature, but requires a considerably higher heat over its boiling point before it will escape with energy from a closed vessel. Even then, owing to its high specific gravity, it will move very much slower than air or steam, The well known formula—

$$\text{velocity}=\sqrt{2g\frac{p^1-p}{s}}$$

in which p^1-p represents the difference between inner and outer pressure, $2g$=64.4=the acceleration of gravity, and s the specific gravity of the gaseous or liquid substance, the specific gravity of the vapors of water and quicksilver at their boiling point being=0.62 : 6.97=1 : 11, proves that under equal pressure steam will escape $\sqrt{11}$=3.3 times quicker.

The necessity of the speedy removal of the quicksilver vapor from an amalgam retort is also proven every day, when the retorted amalgam is removed. The silver is found half, often quite molten, where it touched the iron, showing the high heat employed, whilst metallic quicksilver may be nearly always discovered in the less strongly heated portion. A superficial observer might take that readily as a proof that the heat was not high enough or the time not sufficient, and forget that quicksilver will as little evaporate in an atmosphere saturated with its vapor as any other liquid will.

In conclusion, I hope that if these points seem of sufficient weight to induce the change in the distillation of quicksilver which I have suggested, it will serve to draw attention to the advantages which the distillation in vacuo offers also for other substances, coal-oil for instance. This is a field very little examined into, in which research would certainly be interesting and possibly valuable.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

REGULAR MEETING.

September 5, 1884.

Mr. Geo. W. Dickie in the Chair.

Minutes of preceding meeting read and approved.

Lott Day Norton was proposed for membership by M. Deering, W. G. Curtis and Geo. J. Specht.

The Secretary explained the reason of the delay in the appearance of the transactions, which was owing to the fact that the drawings and engravings of Mr. Specht's paper were burned in the fire which occurred at the ligthographers.

The following were declared elected members:

Victor M. Clement, M. C. Lawlor, P. J. Flynn, E. A Rix.

Mr. Percy made some remarks on the use of concrete in building.

Mr. Dickie called attention to the fact that at the new Union Iron Works, where the floors were laid in thick concrete, there was a horizontal parting of the richer upper layer from the lower layers of concrete, when heavy weights were moved over said floors.

The subject was discussed by Messrs. Dickie, Bowers, Manson and Hoadly.

REGULAR MEETING.

October 3, 1884.

President Mendell in the Chair.

Minutes of preceding meeting read and approved.

The following propositions for membership were made:

W. H. Milliken, proposed by Messrs. Molera, Percy and Yale.

John Henry Clemes, proposed by C. F. Hoffmann, Ross E. Browne and F. Von Leicht.

A paper, "On the Flow of Artesian Wells," by C. E. Grunsky, was read by the Secretary.

Mr. Specht, of the Committee appointed to take steps to establish the unit for measurement of water, asked for further time, which was granted.

W. W. Hanscom submitted the following amendment to Article VII of the by-laws, to take effect, if adopted from January 1, 1885:

The yearly dues shall be as follows:

Resident Member	$8 00
Non " "	4 00
Resident Juniors	6 00
Non " "	3 00
Associates	8 00

Mr F. Gutzkow spoke of the utilization of saw-dust for making wood pulp, by exposing it to the sun and atmosphere, after treatment with "bittern;" that is, a saturated solution of the Chlorides of Sodium and Magnesium. He showed a sample made from redwood in that manner, and directed attention to the facilities which our climate, by its long rainless and sunny season, affords for such process, which would be impossible in most other parts of the temperate zone.

Mr. Gutzkow, described an artesian well in Alameda County, situated on the marsh of the Union Pacific Salt Co., a few feet distant from the mouth of the Mt. Eden Creek. The well is 180 feet deep and discharges, per 24 hours, 50,000 gallons of excellent water, which contains very little chlorides and sulphates, but so much carbonic acid as to hold 80 milligrams of carbonate of lime per litre in solution, and a quantity of bicarbonate of soda, corresponding to about 160 lbs. of sal soda per day. The water discharges at six feet over high water level, but can raise much higher. A pump lifting 4,000 gallons per hour is barely able to lower the water in the well-pipe to the level of the marsh.

During low tide, the flow greatly diminishes. The soil around the well, and for some miles around, is composed of thirty feet of a soft mud, which would close up any outlet if the water supply above feeds the well. Such outlet must be at least as far as the deep water channel between Mount Eden Creek and

Redwood City. That channel is five miles distant and fifty feet deep. It is more probable that the opening is in the ocean itself.

Mr. C. C. Wolcott described a somewhat similar experience in a well sunk on the marsh lands of Mare Island. That well, also, being affected by the tidal flow.

Mr. Poett knew of several such wells, the waters in which rise and fall with the tide. At San Mateo is one sunk within eight or ten feet of the bay, which at high tide flows over, and at low tide is ten or twelve feet below the surface. There are no hard deposits in the marsh, clay and gravel being the most common.

Mr. E J. Molera spoke of the peculiarity of the artesian wells on his ranch in Monterey County. There are eight of these wells, and they seem to be affected by tidal influences. Some of these wells overflow four feet above the ground. The depth where the artesian water is tapped is about 110 feet, just after passing through a certain stratum of clay. The pipes are perfectly tight, and the shore at the edge of the ocean is quite steep. Mr. Molera drew diagrams to show his theory of the cause of the rise and fall in the pipes.

Mr. Wolcott described the progress of the well-sinking opertion at Mare Island

Mr Hermann described the peculiarities of the artesian wells in the Santa Clara Valley.

Mr. Schuyler spoke of the artesian water basin in Los Angeles County. The slope of the valley is about ten feet to the mile, and the flow is carried by the Los Angeles and Santa Ana rivers. The wells occur all the way from the Coast Range down to the sea.

A general discussion took place on the subject of the source of artesian well supply, participated in by Messrs Wolcott, Molera, Poett, Hermann and Hoadley.

The President stated that the Society had been invited to examine the Telegraph Hill cable road, and that he would arrange with the company, and send notice of the day set.

It was also stated that the Society would be able shortly to inspect the new dry dock at Mare Island, and the President was requested to arrange a suitable time and have the members of the Society notified.

THE FLOW OF ARTESIAN WELLS.

By C. E. Grunsky, M. Tech. Soc.

Artesian wells already contribute so much water for agricultural and industrial purposes in this State, while much of the artesian supply is *yet* to be developed, that a few words about their general arrangement and the best means of securing as great a flow as possible, may not be out of place.

It is a strange and surprising fact, that while the casing of an ordinary well is made water-tight solely for the purpose of excluding surface water, the casing in common use for *artesian* wells, in which water is to stand under the pressure of frequently one or more atmospheres, is *not* water-tight.

Through every opening in the casing of an artesian well, when the casing serves, as it almost invariably does, as pipe to conduct the water to the surface of the ground, there is a flow of water due to the particular size and form of opening and the excess of pressure within the casing over that upon its outside.

The greatest loss will occur in water-transmitting strata, where, no matter how great the leakage from the well, the outside pressure is not increased.

The loss will be comparatively slight in clay and other nearly impervious strata which are soon saturated with water, under quite or very nearly the same pressure as the water in the well.

Ordinary artesian well-casing is double. It consists of inner and outer joints, which overlap each other one-half of their length.

The casing is forced into the ground as the boring progresses, by means of powerful levers. It is presumed that the ends of the joints fit snugly against each other. The seam is nothing more than one of simple contact, and cannot be expected to be water-tight, even when well fitting.

The longitudinal seam of each joint is riveted. The rivets are about three inches apart in a single line. This seam is practically water-tight.

The rivet heads of inside and outside casings prevent their perfect contact. Water escaping from the inside casing finds easy passage to the nearest horizontal joint of the outside casing, and there escapes into the pervious strata adjoining, or is held back by the water already under an equivalent pressure in the impervious one, as the case may be.

In Tulare County of this State there are about one hundred artesian wells. Surface water in their neighborhood is from eight to twenty (sometimes more) feet below the surface. The artesian water is generally made to rise two or three feet above the surface of the ground, so that when a "flow is struck," it must be ample to supply the leakage due to a pressure of from ten to twenty-five feet of water, before it will cause the well to flow above the surface of the ground.

In the Tulare County wells, the leakage occurs in sand strata, aggregating more than 100 feet in thickness for wells about 300 feet in depth. The aggregate is greater when the well is deeper. Besides the loss due to leakage when pressure inside is greater than without, there is another, due to an improper system of perforating the casing in those strata which bear artesian water. It is customary to perforate the casing at intervals from top to bottom of the water-bearing strata of sand or gravel.

Water outside, from top to bottom of the strata, has a uniform excess of pressure over that within the casing; consequently each opening in the casing, if we suppose them to be of uniform size, admits the same quantity of water. If there be twenty openings from top to bottom of the strata, and no water enters the casing from below, then it is evident that the upward mean velocity in the casing will be twenty times as great above the uppermost opening as it is just above the lowest. Unless the artesian water flow with unusual force, the result is that particles of sand enter the casing through the lowest slits, and, sinking to the bottom, they gradually fill the well with sand, choking off the flow of opening after opening, no doubt frequently impairing or destroying the flow of the well.

Water should always be admitted through sufficiently large openings near the top of the water-bearing stratum. Only when the stratum next above is soft clay, which is likely to sink into

the water-filled cavity caused by the outflow of sand, ought this rule to be ignored.

Sometimes a number of strata of sand or gravel-bearing artesian water, are bored through before the boring is stopped. The question then arises, shall they all be tapped, or is it policy to exclude some of the weaker flows? The pressure within the casing, at any point, is that due to the height of the outflow of the well above that point No strata send up water to the outflow unless the water pressure in them is greater than the pressure in the casing. But when the flow is a small one from any stratum, and its permanency has not been established, it is always wise to exclude it, provided that in the same boring, other and larger supplies of water have been found. Even a slight decrease in the pressure existing in the stratum which yields little water, may reduce it to less than the hydrostatic pressure in the casing, and immediately an outflow of some of the water from other sources into this stratum, is the result.

When the lowest of the artesian water-bearing strata of any well supplies only a small proportion of its water, then sands, etc., brought into the well through openings in the other strata, sink to the bottom. The well is gradually filled up to the elevation at which water enters with force enough to move sand grains upward. The lowest flow is partially or entirely sacrificed, until the well is cleaned out. The cleaning-out in such a case will be necessary more or less frequently according to the amount of sand moving with the water in the upper strata.

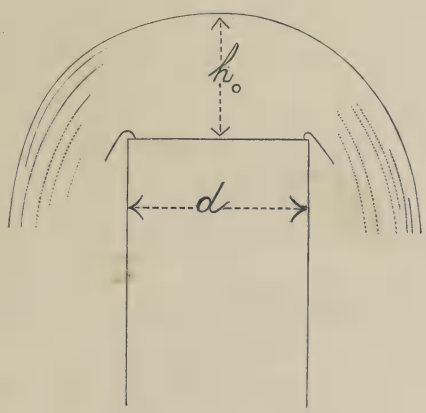
Water should rise in casings or pipes adapted to the flow, having such diameter as to make the upward velocity of the water not less than three feet per second. No water is lost hereby,—the well will never need cleaning.

Estimate of the Flow.—The flow or discharge of an artesian well can be ascertained with greatest accuracy by direct measurement; that is, by noting the time required by the water from the well to fill a measure whose contents are known, or by measuring the quantity of water flowing into a receiver in a fixed time interval. Direct measurement is, however, rarely convenient, except in case of wells of very small flow. As most wells are

allowed to discharge their water over the top of a vertical pipe, where the height to which the water rises over the top can be more or less accurately measured, it has become desirable to find a formula for the discharge in terms of the pipe diameter and the overflow height.

Formulas for the ordinary clear overfall may be used as approximations when the flow from a vertical pipe is small; but it is very evident that when water moves upward through the pipe with a mean velocity of three or four feet per second, it will rise to a greater elevation over its overfall crest than water at rest would stand above it to produce the same flow.

From experiments made in connection with the measurement of many wells in San Joaquin Valley, I have established an empirical formula for their flow, which will be found useful in all ordinary cases



D = discharge in cubic feet per second.

d = inside diameter of pipe.

h_0 = height to which water rises in the centre over the top of the pipe.

h = theoretical height required to produce the same velocity as the mean velocity in the pipe.

c = experimental coëfficient.

v = mean velocity in the pipe.

The empirical formula before modification has the form:

$$D = c\, d\, h_0 \sqrt{h_0 - h} \tag{1}$$

This equation may be transformed as follows:

$$v = \frac{D}{.785\, d^2} \tag{2}$$

$$v = \sqrt{2\, g\, h} \tag{3}$$

Where g is the acceleration due to gravity, $g = 32.16$

From (2) and (3):

$$h = \frac{D^2}{39.6\, d^4} \tag{4}$$

From (4) and (1):

$$D = \sqrt{\frac{39.6\, c^2\, d^4\, h_0^3}{39.6\, d^2 + c^2\, h_0^2}} \tag{5}$$

$$\text{or } D = \frac{c\, d\, h_0^{3-2}}{\sqrt{1 + 0.02525 \left(\frac{h_0}{d}\right)^2}} \tag{6}$$

To determine the value of c, experiments were made which established the correct discharge D for known values of d and h_0.

By transforming (6) it will be found that:

$$c = \frac{D\, d}{h_0} \frac{1}{\sqrt{d^4\, h_0 - 0.02525\, D^2}} \tag{7}$$

The values of c determined by means of this equation did not vary in any case over five per cent. from the arithmetical mean of all the values. The mean error of the individual experiments was three per cent.

The experiments were few in number. They embraced a range of values for h_0 from 0.068 feet to 0.320. The coëfficients established were as follows:

For $h_0 = 0.068$	$c = 9.78$
For $h_0 = 0.200$	$c = 10.23$
For $h_0 = 0.203$	$c = 10.41$
For $h_0 = 0.320$	$c = 9.53$

The lack of uniformity in the values of c, as determined by the experiments, is, without a doubt, due principally to the unavoidable inaccuracy in measuring h_0.

The surface of the water is rarely sufficiently steady above the top of a pipe to permit of an accurate measurement. Generally the water surface has an undulating or wave motion, and the value of h_0 should represent, or rather approximate, its mean height in the centre, not its greatest momentary height. The wave motion of the surface generally increases with increasing values of h_0.

In consideration of the fact that the values of the terms to be used in the formula may themselves be in error, and that a five per cent. limit of error is sufficiently desirable for the purposes of the formula, the results of the experiments were combined and the arithmetical mean of the experimental values of c was accepted as its most probable value. Future examinations may modify it. The adopted value is:

$$c = 10.00$$

and the original formula (1) may be written:

$$D = 10\, d\, h_0 \sqrt{h_0 - h} \qquad (8)$$

The formula can be used in this form by alternatel. approximating values of D and of h, but it will be found much more convenient to use it in the form of equation (6), which, with the value of c inserted, may be written:

$$D = \frac{10\, d \sqrt{h_0{}^3}}{\sqrt{1 + 2.525 \left(\frac{h_0}{d}\right)^2}} \qquad (9)$$

In ordinary use the denominator may be neglected when

$$\frac{h_0}{d} < \frac{1}{10}$$

$$\text{That is } h_0 < \frac{d}{10}$$

For this special case:

$$D_1 = 10\, d \sqrt{h_0{}^3} \qquad (10)$$

To facilitate comparison with the formulæ for an ordinary overfall, l may be substituted for the length of the overfall in this formula, when it will read:

$$D, = 3.18\ l\ \sqrt{h_0{}^3} \qquad (11)$$

Because $l = 3.1416\ d$

Fanning recommends the use of 3.33 as coëfficient where 3.18 appears in equation (11). The peculiar form of the overfall may be the cause of this difference.

Until other experiments establish a more reliable value for c, the equations (9) and (10) may be accepted as the best possible approximation to the flow of water from vertical pipes.

The formula for general use is:

$$D = \frac{10\ d\ \sqrt{h_0{}^3}}{\sqrt{1 + 2.525\left(\frac{h_0}{d}\right)^2}} \qquad (9)$$

and for small values of h_0, when h_0 is less than one-tenth of the pipe diameter.

$$D, = 10\ d\ \sqrt{h_0{}^3}$$

All measurements are to be noted in feet. The flow will be expressed in cubic feet per second.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

REGULAR MEETING.

November 7, 1884.

President Mendell in the Chair.

On ballot, the following were elected members: W. H. Milliken, John H. Clemes and Lott Day Norton.

Hans C. Behr read a paper on the "Maximum Moment of Load in Winding Engines."

The President stated that Major W. A. Jones had tendered his resignation from the Board of Direction, owing to change of residence, and it would be necessary to elect his successor at the next meeting.

Mr. Hanscom asked that the Finance Committee consider his proposed amendment relating to change of amount of dues, and make a report on the subject at the next meeting.

The Committee "On Measurement of Water" was given further time.

The following proposed amendment to the Constitution was read:

To amend Article XIX of the Constitution by changing the word Saturday in the fifth line to the word Friday. (Signed) G. H. Mendell, C. G. Yale, G. W. Percy, W. W. Hanscom and L. Tasheira.

The following amendment to the By-Laws was proposed:

To amend Article I, Section 1, of the By-Laws by changing the word Saturday to the word Friday. (Signed) G. H. Mendell, C. G. Yale, G. W. Percy, W. W. Hanscom, and L. Tasheira.

REGULAR MEETING.

December 5, 1884.

President Mendell in the Chair.

Mr. F. H. Jenssen read a paper "On the Causes of Explosions in the Manufacture of High Explosives."

Mr. Bowie, of the Committee "On the Measurement of Water," reported progress.

On motion of Mr. Hanscom, the following amendment to Section 1, Article I, of the By-Laws, submitted at the November meeting, was adopted:

In Section 1, Article I, substitute the word "Friday" for the word "Saturday."

Mr. G. W. Percy nominated W. W. Hanscom as a member of the Board of Direction, in place of W. A. Jones, resigned.

Mr. Ad. Sommer nominated F. Gutzkow as a member of the Board of Direction, in place of W. A. Jones, resigned.

On ballot, Mr. Gutzkow was elected a member of the Board.

The President read from the By-Laws the section relating to the appointment of a nominating committee to select a regular ticket for officers, to be balloted for at the annual election, and declared nominations in order.

Mr. Mauran nominated Mr. M. Manson; Mr. Hanscom nominated Ross E. Browne; Mr. Dickie nominated E. L. Ransome; Mr. Percy nominated L. J. Le Conte; Mr. Molera nominated H. C. Behr.

On motion, nominations were declared closed and the Secretary instructed to cast a ballot for the gentlemen nominated.

The Chairman of the Finance Committee stated that at the next meeting a statement of the financial condition of the Society would be read.

The subject of the reduction of dues was discussed by Messrs. Sommer, Dickie, Gutzkow and Hoadley.

The President alluded to the recent visit of the members to the works at Mare Island Navy Yard, and stated that the Board of Direction had sent a letter of thanks for courtesies received, to Mr. C. C. Wolcott.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

ON THE MAXIMUM MOMENT OF LOAD IN WINDING ENGINES.

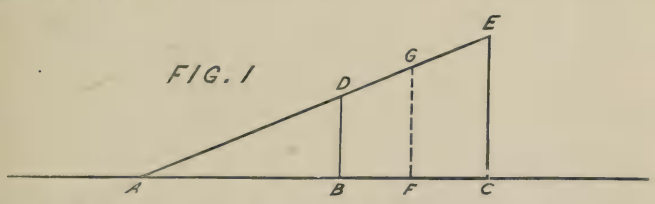
By HANS C. BEHR, M. Tech. Soc.

Read November 7, 1884.

Winding Engines for mining purposes may be divided into two general classes: those employing round ropes and those employing flat ones. The round rope system exists under a variety of forms, and may be classified according to the construction of the winding drum.

The simplest form for round ropes is the common cylindrical drum, upon which the rope is wound in several courses. This is only applicable to short lifts. The great objection to this form is, that the different courses of rope press and wear upon each other.

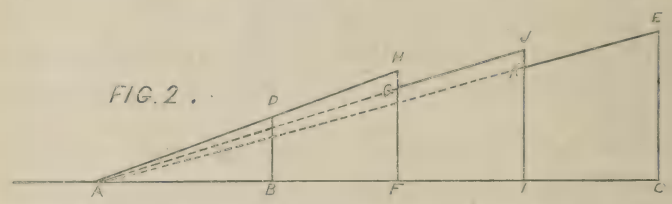
The grooved cylindrical drum, which takes only one course of rope, is free from this objection. This drum must be considerably larger than the one first described in order to hold the same length of rope.



The statical moment of the load in a cylindrical drum is not a constant quantity, because the load varies with the winding and unwinding of the rope, and the maximum moment will occur when the rope is all unwound. The increment of the load is here a constant quantity, being equal to the weight of a coil per revolution. The variation of one course of rope may be represented

by a straight line, the ordinates of which are the moments of the load, whose abscissas are the weight of rope unwound from the drum. If the distance *A B*, Fig. 1, is made proportional to the weight of the load to be raised, and *B C* proportional to the weight of the rope, and if we imagine the whole length *A C* to be wound up, then the moment of load at that point would be zero. The line therefore must cut the axis of abscissas at *A*. The direction of the line will be given by the ordinate *B D*, which is equal to the moment of load at the surface, or to the load to be raised multiplied by the constant radius. The ordinate *E C* will be the moment when the rope is all unwound and any ordinate, as *F G*, will be the moment when a weight of rope, as *B F* is unwound from the drum.

In the common cylindrical drum with several courses of rope, the moment will increase in unwinding according to a certain straight line as *A H* in Fig. 2, until the rope reaches the flange



of the drum, when the radius, and therefore also the moment *H F*, will be decreased suddenly by a distance *H G*, which latter bears the same relation to the moment *H F*, as the thickness of rope bears to the radius. From this point the moment will follow along a straight line that passes through the points *G* and *A* until it receives another decrement *J K* when the line will pass through the points *K* and *A*, and so on for every course of rope.

In Europe it is the practice in mining pits to fix two drums upon one shaft, and so arranged that a descending load assists in raising an ascending one. By this plan the working of both compartments are mutually dependent on each other.

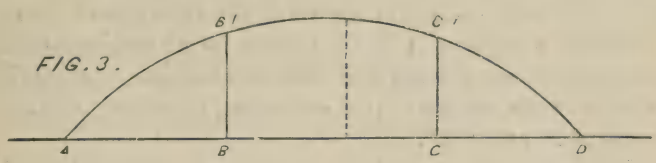
In the United States it has been found more desirable to arrange the drums so that they can be worked either jointly or independently. To accomplish this, the drums are set upon one

shaft and fitted with clutches and brakes for detaching and lowering.

In order to reduce the difference of the statical moments of the ascending and descending loads, permanently connected drums are made of a conical form with end radii that give equal moments at the ends. To obtain a perfectly constant moment for given ascending and descending loads the drums must be constructed according to a curve, the development of which is given by Weisbach in his Mechanics.

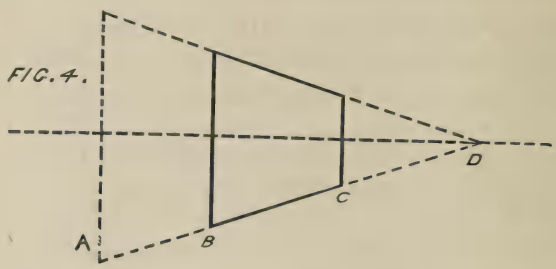
When single or independent working drums are used for great depths, as the work varies in accordance with the change of load to be raised, to avoid too great a variation in the motive power, it is desirable to make the moment of the load as nearly constant as possible. Where water furnishes the requisite power, it is particularly necessary to make the variations as slight as are consistent with the working. This applies likewise in those cases where the descending load is utilized to pump water, as has been proposed in connection with winding engines. In such instances the drums must be calculated to furnish a constant moment for the descending load.

It is therefore obvious that all independent working drums should be made conical, or according to a curve giving a constant moment, either for an ascending or a descending load.



In a simple conical drum with radii for equal end moments, the intermediate moments are all greater than at the ends. This may be demonstrated graphically as follows: In Fig. 3, let *B C* represent the length or the weight of the rope used, and *A B* represent the length or weight of a rope equal in weight to the load to be raised. Let also *C D* be the length that will wind at the same pitch around a cone *C D* Fig. 4, forming the completion of the truncated drum cone to a perfect cone.

Measuring the lengths of rope unwound from the drum as abscissas from B towards C, and laying down as ordinates the corresponding moments of the load, the ends of the ordinates will form a curve representing the variation of the moments. To obtain an approximate idea of the course of this curve, imagine the length of rope $A\ D$, representing the sum of the lengths mentioned above, to be wound up. This length would wind upon a cone $A\ D$, Fig. 4, and as the load is here zero, its moment is



also zero; therefore the curve must pass through the point A. Assuming the length $A\ D$ all unwound from the drum and completing cones, the radius will then be zero, and the moment of the load will be zero at this point. The curve therefore cuts the axis of abscissas at D. The ordinates at B and C, according to the condition of equal moments at the ends of the drum, are equal to each other. By the nature of the variation of the radius and the load, the curve $A\ B'\ C'\ D$ must be of single curvature, and as it is concave toward the axis of abscissas, its maximum must be between any two equal ordinates, therefore between the ordinates $B\ B'$ and $C\ C'$.

To determine the value of the maximum moment of the load, let ρ represent the variable radius of the drum, and W the corresponding variable load. The statical moment of the load will then be expressed by the equation:

$$\rho\ W = u \qquad \text{(I.)}$$

where u is the statical moment.

The quantities ρ and W are dependent upon each other, and one can be expressed in terms of the other. The variable load

W is equal to the constant load w, plus the weight of the rope unwound from the drum.

Let l be the total length of the rope used, and y the variable length of rope wound upon the drum. Then, if m is the weight of one unit of length of the rope:

$$W = w + m\,(l - y) \qquad (1.)$$

The length y is a function of the radius ρ, and can be calculated accurately by the equation for the length of the conical helix. But this equation cannot be solved directly with respect to ρ; it is therefore better to use some formula which will give y as a simpler function of ρ. This can be approximated by dividing the convex surface of that part of the drum, upon which the rope is wound by the pitch or distance between the coils of rope.

Calling r the smaller radius of the drum, and α the angle that the side makes with the axis, the slanting length of this drum up to the radius ρ will be equal to

$$(\rho - r) \sec \alpha$$

The result multiplied by half the sum of the end circumferences gives the surface

$$\pi\,(\rho + r)\,(\rho - r) \sec \alpha = (\rho^2 - r^2)\,\pi \sec \alpha$$

which, divided by the pitch v gives

$$y = \frac{\pi\,(\rho^2 - r^2) \sec \alpha}{v} \qquad (2)$$

If R is taken for the radius of the large end of the drum, and substituting $\rho = R$ in equation (2), the total length l of the rope is obtained:

$$l = \frac{\pi\,(R^2 - r^2)}{v} \sec \alpha$$

From this follows:

$$\sec \alpha = \frac{l\,v}{\pi\,(R^2 - r^2)}$$

Substituting this value of sec α in equation (2).

$$y = \frac{l\,(\rho^2 - r^2)}{R^2 - r^2} \qquad (3)$$

Equation (1) now becomes:

$$W = w + m\left[l - \frac{l(\rho^2 - r^2)}{R^2 - r^2}\right]$$

$$= w + ml\left(1 + \frac{r^2}{R^2 - r^2}\right) - \frac{m\,l\,\rho^2}{R^2 - r^2}$$

$$= w + \frac{ml\,R^2}{R^2 - r^2} - \frac{ml\,\rho^2}{R^2 - r^2} \qquad (4)$$

Finally, substituting this value of (W) in equation (I): there results—

$$\rho\,W = u = \left(w + \frac{ml\,R^2}{R^2 - r^2}\right)\rho - \frac{ml}{R^2 - r^2}\,\rho^3 \qquad (\mathrm{II})$$

differentiating (II) and dividing by $\delta\rho$

$$\frac{\delta\,u}{\delta\,\rho} = w + \frac{ml\,R^2}{R^2 - r^2} - \frac{3\,ml}{R^2 - r^2}\,\rho^2$$

For the maximum this expression becomes zero; therefore

$$\frac{3\,ml}{R^2 - r^2}\,\rho^2 = w + \frac{ml\,R^2}{R^2 - r^2}$$

and from this

$$\rho = \sqrt{\frac{(R^2 - r^2)\,w}{3\,ml} + \frac{R^2}{3}} \qquad (\mathrm{III})$$

For this value of ρ the function u must become a maximum, because the second differential coëfficient is negative.

$$\frac{\delta^2\,u}{\delta\,\rho^2} = -\frac{6\,ml}{R^2 - r^2}\,\rho$$

Substituting the value of ρ from equation (III) in equation (II), there results

$$u_{max.} = \left(w + \frac{ml\,R^2}{R^2 - r^2}\right)\left[\frac{(R^2 - r^2)w}{3\,ml} + \frac{R^2}{3}\right]^{\frac{1}{2}} - \frac{ml}{R^2 - r^2}\left[\frac{(R^2 - r^2)w}{3\,ml} + \frac{R^2}{3}\right]^{\frac{3}{2}}$$

This reduces to:

$$u_{max.} = \tfrac{2}{3}\left(w + \frac{ml\,R^2}{R^2 - r^2}\right)\sqrt{\frac{(R^2 - r^2)w}{3\,ml} + \frac{R^2}{3}}$$

or making the weight ml of the rope equal to p.

$$u_{max.} = \tfrac{2}{3}\left(w + \frac{p\,R^2}{R^2 - r^2}\right)\sqrt{\frac{(R^2 - r^2\ w}{3\,p} + \frac{R^2}{3}} \qquad \text{(IV)}$$

The importance of calculating the maximum moment of the load can be illustrated by a practical example. Suppose a load of 4,000 lbs. is to be raised from a depth of 2,500 feet, by means of an iron wire rope and a conical drum. The weight of such a rope would be about 8,700 lbs. If the radius of the small end of the drum be 48 inches, the radius of the large end will be

$$\frac{4000 + 8700}{4000}\,48 = 152.4 \text{ inch.}$$

The moment of the load at either end will then be 609600 inch lbs., and the maximum moment is

$$u = \tfrac{2}{3}\left(4000 + \frac{8700 \times (152.4)^2}{(152.4)^2 - (48)^2}\right)\sqrt{\frac{(152\ 4)^2 - (48)^2}{3 \times 8700} \times 4000 + \frac{(152.4)^2}{3}}$$

$$= 952735.29 \text{ inch lbs.}$$

In this case the maximum moment exceeds the end moments by over 50 per cent.

Using a steel rope in the preceding case, its weight would only be 2,500 lbs., and the end radius of the large end of the drum would be, using the same smaller radius,

$$\frac{(4000 + 2500)}{4000}\,48 = 78 \text{ inches.}$$

The moment of the load at the ends would then be 312000 inch. lbs., and the maximum only 340169.137 inch lbs., or slightly in excess of the end moments.

The two examples just given illustrate very clearly the advantage gained by the use of steel ropes.

To obtain a perfectly constant moment of resistance for a given weight to be raised by means of a single drum, the function $u = \rho\ W$ would be a constant quantity.

Retaining the meaning of the symbols used in the preceding developments,

$$W = w + m\ (l - y)$$

and

$$u = \rho\ W = \rho\ (w + ml - my)$$

from which

$$\rho = \frac{u}{w + ml - my}$$

To abbreviate, take

$$w + ml = v$$

then

$$\rho = \frac{u}{v - my} \qquad \text{(I)}$$

Equation (I) gives the relation of the radius to the length of the curve generated by its rotation, but does not contain the idea of rotation, which must be introduced to obtain the variation of ρ and y per revolution, and from this finally to get ρ as a function of the width of the drum.

This is accomplished by expressing ρ, y and the angle ϑ to be introduced, in the equation for the length of a polar curve, which is:

$$\delta s = \sqrt{\delta \rho^2 + \rho^2 \delta \vartheta^2}$$

where s is the length of the curve, ρ the radius and ϑ the arc the radius has passed in generating the length s.

In this case $$\delta s = \delta y = \frac{u\,\delta\rho}{m\,\rho^2}$$

therefore $$\left(\frac{u\,\delta\rho}{m\,\rho^2}\right)^2 = \delta\rho^2 + \rho^2\,\delta\vartheta^2$$

from which $$\delta\vartheta = \frac{\delta\rho}{\rho}\sqrt{\frac{u^2}{m^2\,\rho^4} - 1}$$

and $$\vartheta = \int\frac{\delta\rho}{\rho}\sqrt{\frac{u^2}{m^2\,\rho^4} - 1} + C = \frac{m}{u}\int\frac{\delta\rho}{\rho^3}\sqrt{1 - \frac{m^2\,\rho^4}{u^2}} + C$$

By partial integration there results

$$\vartheta = \frac{u}{m}\left(\frac{-1}{2\,\rho^2}\sqrt{1 - \frac{m^2\,\rho^4}{u^2}} - \int\frac{-1}{2\,\rho^2} \times \frac{\dfrac{-4\,m^2\,\rho^3\,\delta\rho}{u^2}}{2\sqrt{1 - \dfrac{m^2\,\rho^4}{u^2}}}\right) + C$$

$$= \frac{u}{m}\left(\frac{-1}{2\,\rho^2}\sqrt{1 - \frac{m^2\,\rho^4}{u^2}} - \frac{m}{u}\int\frac{\dfrac{m^2}{u^2}\,\rho\,\delta\rho}{\sqrt{1 - \dfrac{m^2}{u^2}\,\rho^4}}\right) + C$$

and finally—

$$\vartheta = -\frac{u}{2m\,\rho^2}\sqrt{1 - \frac{m^2\,\rho^4}{u^2}} - \text{arc sin}\,\frac{m\,\rho^2}{u} + C$$

or, $$\vartheta = -\frac{u}{2\,m}\sqrt{\frac{1}{\rho^4} - \frac{m^2}{u^2}} - \text{arc sin}\,\frac{m\,\rho^2}{u} + C \qquad \text{(II)}$$

Since u is always very great compared with m, the term "$\frac{m^2}{u^2}$" under the radical sign and also the term "arc sin $\frac{m\rho^2}{u}$" may be neglected. Take simply.

$$\vartheta = -\frac{u}{2\,m\,\rho^2} + C \qquad \text{(III)}$$

It is here more convenient to determine the constant C, so that ϑ will become zero simultaneously with y. The origin of

co-ordinates then falls at the small end of the drum, the radius of which, obtained from equation (I) calling r, then:

$$0 = -\frac{u}{2\,m\,r^2} + C \text{ and } C = \frac{u}{2\,m\,r^2}$$

Substituting this value of C in equation (III), it becomes:

$$\vartheta = \frac{u}{2\,m}\left(\frac{1}{r^2} - \frac{1}{\rho^2}\right) \qquad \text{(IV)}$$

Not considering, as in the foregoing calculation, the slight effect of the lateral progression of the rope upon the relative values of y, ρ and ϑ, and making ρ in equation (IV) equal to the radius R of the large end of the drum, as obtained from equation (I) for $y = l$, and dividing by $2\,\pi$, the total number N of coils of rope on the drum is obtained.

$$N = \frac{u}{4\,\pi\,m}\left(\frac{1}{r^2} - \frac{1}{R^2}\right) \qquad \text{(V)}$$

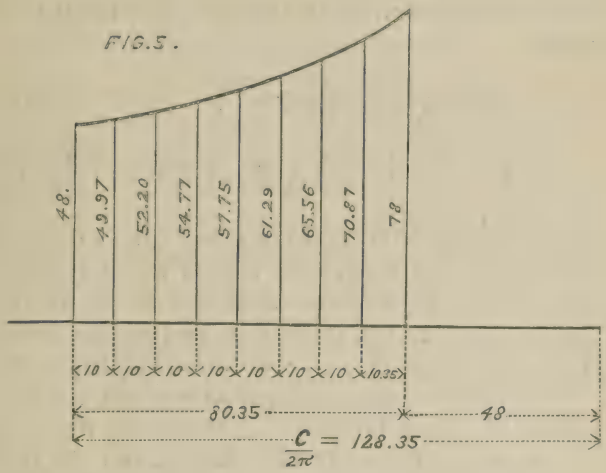
Since the lateral progression of the rope is proportional to the number of revolutions made by the drum, the abscissa or width n of drum for any value of ρ between r and R is obtained by multiplying the corresponding number of revolutions by the pitch or lateral progression of the rope for one revolution. The most direct method is to calculate first the total width of the drum from equation V, dividing this width into any convenient number of parts, and then determine ρ for each point of division, For this purpose express ρ in terms of ϑ by inverting equation (IV), which then becomes,

$$\rho = r\sqrt{\frac{u}{u - 2\,m\,\vartheta\,r^2}} = r\sqrt{\frac{u}{u - 4\,m\,n\,\pi\,r^2}} \qquad \text{(VI)}$$

Taking the data of the example for the steel rope in the demonstration of the maximum moment of load, the curve of a drum of equal moments will be as given in Fig. 5., where the abscissas are expressed in terms of the number of revolutions.

Drums constructed according to a curve are naturally expen-

s.ve, but in case of requirement an approximation to the curve, consisting of two or more simple conical drums, may be employed.



NOTE—Abscissas in terms of number of revolutions.

Generally speaking, the round rope system is open to several objections, which have led to the use of flat ropes. But these likewise have defects, and therefore experience and the requirements of the case must determine which system should be adopted. In this country flat ropes are extensively used, and it is therefore of importance to know the variation and maximum of the moment of the load. The calculation is very similar to that employed in the case of round ropes.

Let ρ, W, w, l, y and m have the same relative meaning as in the case of the round rope. In addition let a be the area of the reel-centre and t the thickness of the rope. Then

$$\pi \rho^2 = a + t y$$

and

$$y = \frac{\pi \rho^2 - a}{t}$$

This substituted in the equation—

$$u = \rho W = \rho [w + m (l - y)]$$

there results

$$u = \left(w + m\,l + \frac{a\,m}{t} \right) \rho - \frac{m\,\pi}{t} \rho^3 \qquad \text{(I)}$$

By differentiating, etc., as in the case of conical drums and round ropes,

$$\rho = \sqrt{\frac{t}{3\,m\,\pi} \left(w + m\,l + \frac{a\,m}{t} \right)} \qquad \text{(II)}$$

and

$$u = \frac{2}{3} \left(w + m\,l + \frac{a\,m}{t} \right) \sqrt{\frac{t}{3\,m\,\pi} \left(w + l\,m + \frac{a\,m}{t} \right)} \qquad \text{(III)}$$

Assuming a load of 4000 lbs. to be raised from a depth of 2500 feet and using an iron rope, such a rope would require to be about $\frac{1}{2}$ inch thick by 5 inches wide, and would weigh about 10,500 lbs, or about .35 lbs. to the inch in length. Taking the reel-centre at 54 inches diameter, its area will be 2290 square inches. When the load is at the top the moment will be 296500 inch lbs. and the radius $74\frac{1}{8}$ inches. When the load is at the bottom the moment will be 391500 inch lbs., and the radius 27 inches. The maximum moment will be 528578.45 inch. lbs. at a radius of 49.25 inches and a depth of 888 feet 2 inches.

Substituting a steel rope for the same depth and load to be raised, it will only require to be $\frac{3}{8}$ inch thick by 3 inch wide and its weight would be 5700 lbs. or about .19 lbs. per inch of length. The end and maximum moments will here be as follows:

	Moment of Load.	Radius.	Depth.
Top.....	262600 inch lbs.	65.625 inches.	0
Maximum.....	445057 " "	51.9 "	1028 ft. 8 in.
Bottom.....	315900 " "	27, "	2500 ft.

For deep mining, the round rope system on a simple conical drum, and the flat rope-reel, are the chief ones to be considered. The advantages of the flat rope system are, first, the small space occupied; second, that the view of the engine runner, who generally stands behind the reel, is not so much obstructed, so that he can see what is going on at the mouth of the pit; and third, that the line of winding is always in the same plane, and the rope is not subject to side strains.

The objections to flat ropes are—

1st. That the wires are liable to be strained unequally.

2d. That the rope winds, presses, and wears upon itself, and is therefore liable to more rapid destruction.

3d. That the rope will pack tighter upon the reel, when raising a heavy load than when raising a light one, and therefore the mechanism attached to the engine, and intended to indicate the position of the cage or load in the shaft, will not give this position correctly. This is especially the case near the surface where correct indication is most necessary in order to avoid accidents from over-winding.

4th. The difficulty of constructing flat taper ropes, as they should be of even width to occupy the space between the reel arms, and should only taper in thickness.

The advantages of the round rope system are, first, that lighter ropes can be used, because flat ropes must be taken of larger cross sections, on account of the liability of unequal straining in the different strands. Second, the ropes are less liable to wear when laid in grooves.

The objections are, first, that the drums must be made very large in diameter and width in order to hold the required amount of rope. Second, that the rope does not wind upon the drum in the same plane, forming an angle with the groove in the drum which is greatest at each end, and that to reduce this angle and the strain resulting from bending the rope at this point, the drums must be placed at a comparatively great distance from the pit. Another objection to round ropes is that they are liable to corrode from the centre, where the corrosion cannot be detected. This is especially the case when hemp cores are used, which are liable to hold moisture.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CAUSES OF EXPLOSIONS IN THE MANUFACTURE OF HIGH EXPLOSIVES.

By FRED. H. JENSSEN, Ph. D., M. Tech. Soc.

Read December 5, 1884.

In treating the subject of this paper, viz: Causes of Explosions in the Manufacture of High Explosives, the writer gives for the most part, results drawn from his own experience extending over a period of the last ten years, during which time he was connected with the management of the principal Dynamite factories of Europe and America.

It has been considered desirable and valuable for those interested in the manufacture, as well as for those who use or experiment with high explosives, that any and all information on this important subject should be collected and made a matter of record. By this means it is hoped that sufficient data will be obtained, which will assist materially in the investigations of the causes of such explosions, and enable the adoption of means to prevent them.

The visitor to the scene of a powder-mill explosion, immediately after its occurrence, who seeks an explanation of the disaster, finds that in most cases there is no living witness left to account for the accident, and its causes remain covered with a veil of mystery. The seat of the most violent explosion is marked generally by a large hole, while splinters of wood and pieces of metal of all sizes and shapes and the mangled remains of unfortunate victims are found scattered here and there over the premises. In some instances a few have escaped with their lives. It has occurred occasionally that explosions have been prevented in factories by the prompt and heroic action of individuals in the face of almost certain death. To the survivor and the man who has prevented it, one must look for information which will assist in the investigation of those explosions, the causes of which are not evident.

Explosions have occurred ever since powder has been manufactured. It is only a few years ago that at some of the Dynamite works, a premium was given to those superintendents at whose works no explosions occurred during the year. Suffice it to say few premiums were ever received.

From 1869 to 1872, explosions at manufactories in Europe were of common occurrence, but during the last twelve years there have been very few disastrous ones. With the limited knowledge now available, and even with a more extended experience, it hardly can be expected that explosions at manufactories will be prevented entirely. In California they are of such common occurrence as to occasion but little comment, though the last three years there have been several accidents attended with fatal results, two of them causing a loss of nearly eighty lives. In Europe, from 1874 to 1881, few explosions occurred, and in the twelve factories with which the writer was connected, the loss of life did not exceed ten or twelve. Since that time, several very serious explosions have taken place in those works. At one of these factories near Hamburg, which had been run without accident since 1871, eight men were killed inside of a month. At another works near Glasgow, Scotland, ten men were killed this spring. The total number of lives lost at the twelve works during this period does not exceed twenty-five.

Explosions in most cases can be traced to the following causes:

1. Improper construction and faulty arrangement of the works and machines.

2. Carelessness on the part of workmen.

3. Maliciousness.

The explosive which is manufactured most extensively on this coast is Dynamite. The trade names, Hercules, Giant, Vulcan, Safety Nitro Powder, are here given to high explosives. All these powders are dynamite Dynamite, according to the definition of the inventor, Alfred Nobel, is a combination of nitroglycerine with an absorbent, which is exploded by a cap or de-

tonator. Therefore, a compound which contains nitro-glycerine, no matter what the percentage, or what the absorbents may be, is dynamite. Powder, or black powder, generally is a combination of nitre, sulphur and coal, which is exploded by a spark.

1. *Explosions due to improper construction and faulty arrangement of the works.*—Factories for the manufacture of explosives, on account of the danger of loss of life and to property, should be built by men especially experienced in that particular business. Many European States have laws to the effect, that franchises for erecting and operating powder factories, are only given to men who have had from two to five years practical experience in such works, and eligible superintendents are required to have been engaged in the manufacture of explosives a specified number of years. Superintendents of dynamite works are required to have a knowledge of chemistry, and chemists are employed generally for these positions. In the United States, the government interferes but little with the manufacturers of explosives.

The two methods employed for the manufacture of nitro-glycerine by Nobel and Mowbray, can be described briefly as follows:

Mowbray makes small quantities in a series of pots, and Nobel makes from 200 to 2000 lbs. in one apparatus, in one operation. In the manufacture of nitro-glycerine by whatever method employed, there are certain points which are alike in the mixture of nitro-glycerine and acids. The specific gravity of glycerine not being as great as that of the mixed acids, the stirring of the acids during the time that the glycerine enters them must be fully sufficient to prevent the glycerine from floating and accumulating on top of the acids. Should the glycerine float, it would catch fire, owing to its rapid oxidation. This reaction is very stormy, and the decomposition on account of the great quantity of hyponitric gases developed, is communicated to the nitro-glycerine already formed, so that it takes only a few seconds to produce and accumulate such an immense degree of heat that the remaining nitro-glycerine takes fire. If the quantity of nitro-glycerine is large, an explosion takes place inside of three or four minutes, unless the arrangements are made in such

a way that the supply of the glycerine is shut off immediately and a stronger stirring keeps the whole mixture in a continuous motion, or that the contents of the pot or apparatus are thrown into a large quantity of water. Several explosions occurred in this part of the process in the first years of the industry, but only a few lives were lost, as there was sufficient time for the men to get under shelter. The last explosion due to this cause at Nobel's factories in Europe, occurred in May, 1872, though no one was injured. Since that time, although decompositions in the apparatus have taken place frequently, the explosions have been prevented by the means above mentioned. Should the stirring machinery give out and the dark red flames show themselves through the cover of the apparatus, filling the building with strong nitrous gases, it requires considerable nerve to approach the stop-cock, to turn it off in order to run the contents into the water. Therefore, this place should be occupied only by the most reliable, cool headed and experienced man. The writer prefers always to make the nitro-glycerine himself, rather than to leave it to any one who has not gone through this experience.

With the Mowbray method, although small quantities are made in each pot, the increase in the number of pots requires a corresponding large number of men. Hence the chances for accident are greater than where a larger quantity of nitro-glycerine is made at a single operation and the responsibility devolves on a single individual.

The writer has found it convenient on this coast to combine the two systems. Two Nobel's apparatus have been built, one alongside of the other, so that they can be attended to by one man, each apparatus having a capacity of one ton of nitro-glycerine. This special plan is here carried out on the largest scale known. Three men run the works, and produce daily six to eight tons of nitro-glycerine. The only other employees are a few men engaged on outside work, carrying the acids and the glycerine for charging purposes, and removing the empty carboys and casks.

When the glycerine and acids have been thoroughly mixed, and all the nitro-glycerine formed, in regaining the acid, which is always present in excess, and which it is desired to save for

future use, there is danger of an explosion. Several accidents have occurred in separating these acids from the nitro-glycerine.

Generally the contents of the apparatus or of the series of small pots are run into a large tank filled with water, where the acids are dissolved, and the nitro-glycerine being of greater specific gravity, settles to the bottom. This tank must be large enough so as to prevent an increase in temperature. At 100° F. the acid nitro-glycerine decomposes and is very sensitive. It is necessary to keep the nitro-glycerine under the first water for the shortest possible time, and to change the water or to draw the nitro-glycerine into another tank, where the washing or neutralizing may be completed. In these operations there is no attendant danger, provided the nitro-glycerine is not exposed to friction or shock. Acid nitro-glycerine should not be stored or kept over night. Should the pipe lines, which connect one tank with the other, cross steam or hot water pipes, an explosion can occur, if great care is not taken. The two pipe lines never should be close together, as small particles of nitro glycerine always remain in the tank pipe, and readily decompose when exposed to continuous heat.

All leaks must be guarded against most carefully. Only a few years ago, two accidents occurred, due alone to this cause.

All stop-cocks, through which the nitro-glycerine passes, must turn easily and without friction..

As the water and the carbonate of soda, which have been used to wash and neutralize the nitro-glycerine, carry small globules of it partially in suspense or attached to impurities in the water, such as sulphate of lime, clay and dust, another opportunity for an explosion here exists.

To avoid accident and for economy's sake, arrangements should be made to catch as much as possible of this nitro-glycerine before discharging the water; but where the waters are run off, they should be conducted through earthen ware or leaden pipes, and taken by the shortest line into a river, bay or well. If wooden conduits, which become readily saturated with acids and nitro-glycerine, are used, they should be well covered to protect them from the heat of the sun, which dries the wood and

thus causes decomposition, resulting in either explosion or conflagration.

At a factory where no arrangements had been made to catch the traces of nitro-glycerine, the wash-waters ran a short distance over a sandy beach before entering the river. The result was, that on a hot summer's day, red fumes of hyponitric acid were observed rising from the ground and a heavy explosion soon occurred on the beach.

At another powder factory where the wash water had been conducted through a ditch in rocky ground, it was subsequently discovered that the rock was fissured, and that a large amount of nitro-glycerine had accumulated in the seams. To remove this, numerous attempts were made, which were partially successful; but as the work was very slow and dangerous, it was concluded to dam the ditch, and keep the fissured portion permanently under water, wherever the nito glycerine could be traced. Several years passed, when suddenly, during a heavy storm, the middle of the ditch was struck by lightning. A terrific explosion immediately ensued, damaging severely all the buildings in the vicinity, and hurling to a great distance vast masses of rock.

In the department where the nitro-glycerine is mixed with the absorbent, there is no immediate danger, except through gross ignorance in the arrangement of the works, or the absorbent itself is of a dangerous character. The mixing is done generally by hand or with rackets of wood or rubber in wooden boxes which are sometimes lined with lead. The explosives are passed usually by hand, or with the assistance of small pieces of wood, through a brass sieve. If the absorbent is too warm, an explosion can take place in the mixing-house. The absorbent is dried before it is mixed, and the drier it is, the better the powder. It is hygroscopic, and therefore should be taken from the drying directly to the mixing pan. Should it be too hot, the nitro-glycerine will decompose and an explosion, or at least combustion, will occur.

The dust, which arises from the mixing pan, settling everywhere in the building, is a source of great danger. Therefore, the hot water or steam heating pipes should be covered, so that the heat may enter the room, and the dust prevented from set-

tling on them. Moreover, they should be cleaned regularly, so as not to give the small particles of nitro-glycerine contained in the dust an opportunity to decompose. Nitrated cotton, when used in a dry and finely pulverized state to manufacture Nobel's explosive Gelatine, makes a great deal of dust, and special care must be taken that this dust does not remain during the night on the pipes. An accident which happened several years ago in the mixing house of an Italian factory, has been attributed solely to this cause.

Direct heating with stoves should be avoided, and in Europe is not allowed. The hot water heating system is now in general use. Since its introduction, accidents in the mixing as well as packing department have decreased. The furnace for the hot water system must be situated or so arranged that no sparks from the chimney or from the hot ashes can reach the explosive, or the buildings where it is handled. An accident on this coast two years ago, where many lives were lost can be traced to this cause, although it was attributed also to the carelessness of the man in charge of the furnace. The circumstances were as follows: The explosive whilst being carried in boxes by two men from the mixing to the packing houses, passed immediately in front of the hot water furnace, where the fireman was stoking the fire and drawing out the hot ashes. The prevailing wind carried a spark into the box of powder, which immediately took fire and exploded, setting fire to and exploding almost the whole explosive department of the works.

In the packing department, the arrangements are in accordance with the nature of the explosive manufactured. The Kieselguhr Dynamite is pressed by machines into cartridges. A brass piston worked by a lever, through a thin brass pipe, around which the cartridge paper has been folded, presses the loose dynamite into the cartridge Several accidents have happened with these machines, which, so far as ascertained, were caused by the piston not running straight into the tube, touching one side of it, causing friction. To obviate this, the end of the piston has been made lately of bone, which is a decided improvement on the metallic head.

Explosive gelatine and gelatine dynamite, according to their

pasty quality, are pressed by an arrangement similar to a water screw, into the brass tube, and no accident to the writer's knowledge has happened yet, and none is likely to occur, if the proper care is taken.

Other dynamites, similar to those used on this coast, which contain nitre, wood pulp or coal, are pressed into the paper cartridges by hand with wooden sticks, through funnels of tin foil or tinned iron. A machine has been patented lately, where several cartridges are made at the same time by means of an arrangement of sticks handled by one man. With the old plan there is no danger, unless the sticks, tables and boxes with which the loose dynamite comes in contact, and which naturally becomes saturated with nitro-glycerine, are exposed to a heavy shock or friction.

In this, as well as in the mixing department, a very careful arrangement of the heating pipes is necessary, and care should be exercised, so that no dynamite comes on top of or near those pipes. Moreover, in both of those departments, no pieces of metal or tools, hammer, screws, etc., should be allowed or even hung on the walls. If they are required, they should be used only by the foreman after the dynamite has been removed, and should then be put in a place to which the foreman alone has access. A recent explosion in England is said to have been caused by the falling of a metallic instrument from the wall on a quantity of powder in a box with metallic corner pieces. The explosion killed ten men and wounded five more or less seriously. Although several other accidents have happened in the packing department, it has been very difficult to ascertain the real cause, as a large amount of explosive matter is kept in those buildings, and when any explosion occurs, no one is ever left to tell the tale.

In all these departments, the arrangement should be so made, that the spilling of nitro-glycerine or dynamite is avoided, and the machines and the floors can be repeatedly cleaned without difficulty. Cleanliness and accuracy are prerequisites for safety, and cannot be over estimated. The windows should be provided with curtains, or so arranged that the sun cannot shine directly on the nitro-glycerine or the dynamite. The direct heat of the

sun causes decomposition to ensue, acid nitro-glycerine decomposing readily in the sun's rays.

However perfect the arrangements may be, it is still more important to understand the nature and chemical composition of the explosive. In Europe, before an explosive product can be introduced to the trade, it must be submitted to certain mechanical and chemical tests. When these are satisfactory, the explosive can be manufactured. In the United States, there is no general law on this subject, although transportation companies have in some instances endeavored to regulate the transportation of powders. There are mixtures of nitro-glycerine and absorbents, which are so sensitive that not only the transportation, but even the handling is attended with great danger. Chlorate of potash and charcoal, and even picrates are used, but luckily for a short time, as an explosion in the works or mines, very soon discloses the dangerous nature of the article, and puts a stop to its manufacture.

2. *Carelessness of the Workmen.*—As the explosive must be manufactured and undergo different manipulations, an opportunity for the workmen or others maliciously disposed to cause an explosion, will always exist. Wherever the arrangement of the works are imperfect, there is more opportunity for error, and more accidents will occur. It is impossible for the superintendents and foremen to watch employees at every moment, and opportunities will always occur, particularly when the work is pressed, at which times the workmen do not carry out strictly their instructions, oftentimes trusting the explosive, contrary to orders. A close supervision will prevent many accidents, but that alone is not sufficient. The impression prevails with some owners of works that powder factories should employ old hands as long as possible, as they are supposed to know exactly how to handle the explosive, how to act in emergencies, and to appreciate fully the danger. Others experienced in the powder manufacture, consider that the factories should keep men but a short time, claiming that the men become too confident of themselves and do not obey orders, whereas new men, having no experience, follow instructions implicitly, fearing that the slightest disobedience would cause immediately disastrous results.

It is very difficult to determine which is right, but in the experience of the writer, very few men can be trusted implicitly in any capacity, and in his opinion, where a man is found who realizes his responsibility and acts accordingly, he should be retained—all others should be changed frequently.

In the nitro-glycerine department, men should be retained in their employment as long as possible. There are occasions where, to avoid accidents, experience is absolutely necessary. Apart from the handling of the acids and nitro-glycerine, the testing of the apparatus and pipe-lines, before the manufacing commences, and the keeping in order of the stop-cocks, (where such are used,) can be done properly only by experienced and reliable men. The man who has charge of the neutralizing of the nitro-glycerine, must be thoroughly competent and reliable. Dynamite containing nitro-glycerine, not absolutely free from acids, is dangerous to handle or store. This is likewise the case with nitrated cotton used for Nobel's Explosive Gelatine and Guncotton.

The mixing and packing departments require experienced foremen. Other employees, if inexperienced, should be supervised closely. At European works, only two to six men work in a house. Green hands are never left alone, but work with experienced men, who teach them to run the machines already described.

Explosions on account of carelessness occur principally on a Monday or day following a holiday, or when under pressure of business attempts are made to crowd and incautiously hurry up the work beyond the capacity of the factory.

3. *Maliciousness.*—Explosions caused by maliciousness are difficult to investigate, on account of the result, which helps the offender to conceal his crime. Such frightful acts are known to have been committed for the purpose of concealing larceny, to gain employment, or to revenge some fancied wrong against an officer of the works.

About ten years ago, a peculiar case came under the observation of the writer whilst employed as assistant superintendent in one of Nobel's dynamite factories in Austria. One afternoon,

the foreman of the mixing department hurriedly came to him, bringing the heads of four phosphorus matches which he had found in the dynamite whilst sifting it. He immediately stopped work, and reported to the writer for orders. About six hundred pounds of dynamite were believed to contain matches, and this powder was being distributed in the packing houses. All of this material was returned forthwith to the mixing house, and the employees removed from the buildings. All the suspected dynamite was then taken by the writer and foreman and passed very slowly and cautiously with the hands through sieves. Sixteen phosphorus tips were found, some of them only after the dynamite had passed the second time through the sieves. When the dynamite was considered sufficiently safe, it was formed by hand into cartridges, fearing that the machines, in spite of all the caution taken, might encounter a piece of phosphorus, and the friction would explode the powder.

The match heads were tested subsequently, by gentle rubbing, and exploded readily. Further investigation elicited the fact that the matches had been placed in the bag containing infusorial earth, which had remained over night in a store room adjoining the engine house, to which place the men who brought ice to the ice house had access. One of these men was suspected, and although a large reward was offered and the closest examination made, the culprit was not discovered.

It is difficult to say how to guard against such cases. As a rule strangers should not be allowed on the premises, and even when the works are not running, they should be guarded carefully. This at least would make it more difficult to commit crimes, but to render it impossible is almost beyond human power.

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XI.

(VOLUME II. — JANUARY, 1885.)

THE DESTRUCTION OF THE ENGLISH DAM.

By AUG. J. BOWIE, JR., M. Tech. Soc.

Read January 4, 1885.

The Rudyard reservoir of the Milton Mining and Water Company, situated on the headwaters of a tributary of the Yuba river, in Sierra County, California, at an elevation of 6,140 feet (baro. obs.) above sea level, was formed by means of three timber crib dams. These structures, built in 1856–58, by an English company, were known familiarly as the "English Dam." The North Bloomfield Gravel Mining Company purchased this property in 1867 and sold it in 1872 to the present owner.

The reservoir, fed from a gross catchment basin of 12.1 sq. miles, covered at high water level (of the destroyed structure) an area of 395 acres, impounding 650,000,000 cubic feet of water. The middle dam, the largest of these three works, and the subject of the present paper, had, when destroyed, a vertical height on the interior of 100 feet, and on the exterior of 131 feet from the deepest part of its foundation. Its total length at the crest was about 331 feet, with a minimum bottom length of about 50 feet. (See Plates II and III). The total distance across the base measured, at right angles through the culvert from the face planking to the face of the lower outer wall, was about 185 feet.

The original dam, which was of the ordinary timber crib style (the cribs being built of tamarack and filled in with stone) had a total width across the base of 100 feet, measured through the culvert, with a vertical height of 79 feet above datum line, on the inside face. This face was covered with a heavy pine planking, forming a water-tight lining to the dam.

When this reservoir was purchased by the North Bloomfield Gravel Mining Company, as it then had no immediate use for the water, the waste way of the dam was cut down 8 feet. As a small amount of water was observed flowing under the bottom of the crib of the middle dam, earth was taken from the sides and filled in on the inside of the dam to stop this leak. (See Plate I.)

The slope of the face of the inner planking was 60° from horizontal, and that of the outer crib work was 58°.

In 1876–77 the outer face was overhauled, and that portion of the old crib partially decayed, was torn out and replaced with new timbers.

With a view of increasing the capacity of the reservoir, which necessitated raising the crest of the dam, it was deemed advisable to strengthen the structure with a stone facing on the outside. To carry out this improvement, a tramway passing along the entire crest of the dam, was built to a quarry about a mile distant. This rock was trammed to the dam, where an outer face wall of dry rubble stone was gradually raised on a slope of 44°, and the intervening space filled in solidly with stone dumped from cars.

The material used was a trachytic tufa (?) of 2.4 to 2.6 specific gravity, the best there obtainable. It was estimated that in the quantity used the ratio of the dead weight to the pressure on the bottom of the dam was 19,200 lbs. to 5,400 lbs. per square foot, which made the new dam stronger than the old structure. (See Plate I.)

In 1878, when this stone work was completed to within 7 feet of the intended crest, a substantial piece of timber work thoroughly braced, having a greater resisting power in proportion to the pressure than any other portion of the structure, was raised on the top of the dam, carrying up the inside water face to the

full projected height.* The high-water mark was then raised 7 feet, or to a point 86.73 feet above the bottom of the inner mouth of the culvert.

The ultimate design of the company was to tear out the old wooden water face lining, and carry up from the bed rock a dry stone face wall to within a reasonable distance of high-water mark, and joining at the crest with the outer face wall, thus completing the dam. (See Plate I.) Before completing the structure it was deemed proper in the interval to allow the new stone filling on the outer side to settle, hence the work was not finished as contemplated at the time of the destruction of the dam.

From 1858 to June, 1883, inclusive, the water in the reservoir was raised annually to the high water mark, which in the new structure was 14 inches below the crest of the new timber work, and no sign of weakness or leakage was ever observed.

On the evening of June 17th, 1883, the dam, as was the daily custom, was examined carefully by the men in charge, and reported to the Superintendent in perfect order. The gauge that evening showed the level of the water to be within 16½ inches of the crest. The gates were open delivering water to the ditch, and none running over the waste way. The following morning at half past five o'clock, the watchman making his early inspection, heard after crossing the south dam, when within 300 feet of the middle dam, two violent explosions. On reaching a point where the main central dam was visible, the water was seen pouring through an opening in the upper timber work, over the crest of the stone work, though the gauge at the south dam showed that it still required 2½ inches to reach the waste way or high water level. In a few moments the crest in the centre of the dam, for a length of 175 feet, was swept away and an immense opening soon cut to its very foundation.

In the space of one hour fully 600,000,000 cubic feet of water were discharged into the cañon below, at the rate of over 166,000 cubic feet per second. Within an hour and a half from the time that the explosion occurred, the reservoir was emptied of its entire contents of 650,000,000 cubic feet of water. This im-

*The total cost of these improvements was about $70,000.

mense volume rushed into the cañon below the dam, which for the immediate distance of about 1,000 feet has an average width at the high water level of the dam of 300 feet, and a bottom width of 100 feet. (See Plate II.)

This cañon has a grade of about 500 feet to the mile, and along the distance mentioned is denuded entirely, whatever formerly existed here having been swept away.

The first indications of any deposit from the stone in the dam are observed at a point about 1,500 ft. below it. Here the cañon widens, and a deposit which is 8 or 10 feet high, composed of gravel, mud, and rock, extends along the south side some 500 or 600 feet. Stones of various dimensions, containing as much 4 or 5 cubic feet, are observed to have lodged here. As these remain undisturbed, and the deposit never has been examined, it is fair to suppose that the larger rocks, weighing several tons, which are said to have been in the foundation of the dam and which are now no longer visible, are to be found in the deposit under the debris, though possibly some of them may have been broken, leaving these fragments. That they could have been transported any great distance in their original size is improbable, owing to the topography of the country and the known velocity of the water, as at and below this noticeable deposit, the stream becomes so wide that the water lost its transporting power.

As soon as the break occurred, the news was telephoned along the line, and every one that could be reached along the river was notified of the coming waters.

There are many places in the cañons of the middle Yuba where the flood is believed to have reached a height of from 75 to 80 feet, and it was observed by those who saw the rush in these places, that the face of the torrent was a mass of timber and trees, no water being visible.

At Freeman's Bridge, 43 miles below the dam, which point it reached at 9:30 A. M., a rise of 40 feet is reported. The water reached the Narrows a short distance above Smartsville, and about 65 miles from the dam, having descended 5850 feet (baro. obs.) in 6 hours and 15 minutes, or at a maximum rate of 10.4 miles per hour, or 15.25 feet per second. Here the river is 265 to 285 feet wide at the water line, and the rise due

to this flood was reported to be 35 to 40 feet.* The total time occupied by the wave in passing here was not noticed.

The next observation was at Point de Guerre, 70 miles from the dam, and 5 miles below Smartsville. The river at this place is about a mile wide and widens as it enters the valley. In 15 minutes it rose 2½ feet with strong waves washing the shore. This place is 6020 feet below the dam (baro. obs.) and 180 feet lower than Smartsville. Official information gives the time of the arrival of the water at Point de Guerre at 12:45 P. M., which makes the average velocity of the flow of the first wave from the dam to this place, 9.65 miles per hour, or 14.16 feet per second, or from Smartsville 5 miles per hour, or 7:33 feet per second. As the length of the wave in passing Smartsville and Point de Guerre was not observed, the mean velocity of the entire flow cannot be computed.

In descending the river below Point de Guerre, a poorly constructed levee on the south side of the Yuba gave way, and a large volume of water poured through the breaks and passed over some 7 miles of farming country (thickly settled) in the midst of harvest, resulting in the destruction of only some four thousand dollars worth of property.

At Marysville the river commenced to rise at 3 P. M., and between 3 and 4 P. M., the gauge at the bridge is said to have indicated 7 inches rise; by 5 P. M., 1 foot rise, and the maximum point was reached at 7 P. M., when the gauge registered a rise of 2 feet 8 inches. From this time on the water began to fall, the river assuming its normal state, though no record of that hour has been obtained. The average velocity of the foremost wave from the dam to Marysville can be estimated at 8½ miles per hour, or 12.46 feet per second; or from Point de Guerre, 6.66 miles per hour, or 9.77 feet per second, and from Smartsville to Marysville, 6.15 miles per hour, or 9.01 feet per second.

Distance from Dam to Marysville	85 miles.
" " Marysville to Smartsville	20 "
" " " Point de Guerre	15 "

*This rise was due to the accumulations of timber and trees, which held back the water.

The final observation of this flood was made at Sacramento, 140 miles distant from the dam, or

From Smartsville	75 miles.
" Point de Guerre	70 "
" Marysville	55 "

Elevation of Sacramento above mean sea level at low water level, 6 feet.

Total grade or fall from dam, 6134 feet.

The gauge at foot of K street, on the Sacramento river, registered at 6 P. M., June 18th, 1883, 14 feet, 4 inches.* The first indication of the arrival of the water from the dam, was the appearance of muddy water at 6 A. M., June 19th. At 8 A. M., the gauge indicated 14 feet 9 inches. From 2 to 3 P. M., the water was extremely muddy. At 4 P. M., the gauge read 15 feet, and at 5 P. M., it registered 15 feet and ½ inch, which was the maximum height of the wave. At 6 P. M., the gauge stood 15 feet; at 7 P. M., 14 feet 11½ inches; at 7:30 P. M., 14 feet 11 inches, and at 8 A. M., June 20th, it registered 14 feet 2 inches, or 2 inches below its register of June 18th.

The total time occupied by the wave in passing Sacramento was 26 hours, and assuming that the entire quantity of water from the dam was discharged by 6:15 A. M., June 18th, the mean between 5:30 and 7 A. M., when the dam was entirely emptied, the average velocity of the flow between the dam and Sacramento was 3.8 miles per hour, or 5 58 feet per second.

With the exception of the destruction of the L'Habra Dam,† in the Province of Oran, Algeria, which contained a thousand million cubic feet of water, this is probably the largest quantity of water ever set free at once from an artificial reservoir, in the history of the world. Taking into consideration the elevation of this storage reservoir and the tremendous descent of the water, 6,134 feet in 140 miles, the small amount of damage caused by this accident is unparalleled.

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*This is the old gauge whose present low water plane is 5 feet 4 inches above the old low water level.

†Proceedings of the Institution of Civil Engineers, London, vol. 70,

The capacity of the water ways of this State in comparison with the requirements of the drainage area is insignificant, and it is a well established fact that the river channels without the streams overflowing their banks on the adjacent lowlands* are or were always wholly insufficient to contain at high flood water, the drainage of the country.

In substantiation of these facts may be cited the report of the State Engineer, 1880, pp. 7 and 8, where in speaking of the Sacramento Valley, it is stated that it has an area of 4,769 square miles, classified as follows:

DESIGNATION.	AREA SQ. MILES.
High hill lands	55.50
Low hill or rolling land near foothills	650.00
Dry plains above reach of all overflow	2,321.45
Dry plains subject to occasional overflow from tributary streams	450.00
Lands covered by debris, subject to flooding; river bottom or marginal lands, subject to temporary annual overflow; low basin lands, not tule swamps, naturally subject to deep annual flooding; low basin lands, tule swamps, naturally subject to protracted deep annual flooding; island swamp lands and other tule swamps, naturally subject to flooding by high tides	1,254.00
River, slough and channel surface of perennial streams	38.05
Total,	4,769 sq. miles.

The watershed with the drainage tributary of the Sacramento in combined area, is more than 2½ times the superfices of the valley itself. The Sierra Nevada side, drained by the American, Bear, Feather and Yuba rivers, Butte, Chico, Rock, Deer, Mill and Antelope creeks, has an area of 8,298 sq. miles, with elevations from 7,000 to 11,000 feet, receives annually from 24 to 102 inches of precipitation in form of rain and snow.† The entire drainage basin of the Sacramento River aggregates about 25,000 square miles.

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*Colusa, Butte, and Sutter basins, above Feather River, Yolo and American basins, and all the land bordering the river from Sacramento to Grand Island.

†See report of State Engineer, 1880, p. 8.

It is therefore not strange that in the flood of March, 1879, it appears according to the authority of the State Engineer, that in the lowlands of the Sacramento, about 847 sq. miles were submerged. Above the mouth of the Feather River, in the upper flood region, about 483 sq. miles, and below that point in the lower flood region, about 364 sq. miles were covered with water.

As the rise of water caused by the destruction of the English Dam, occurring as it did at midsummer, raised the waters at Marysville only 2′ 8″, and at Sacramento only 8½″, it is evident to any engineer, from an examination of the official maps of the State of California, and of the map attached to the report of the "Debris Question," by Lieut. Col. G. H. Mendell, Corps of Engineers U. S. A., to the Secretary of War, that had this flood taken place during high water, it would never have been observed by a marked increase in the level of these streams.

This would be due to the fact that the increased water way area over the lowlands (which are river channels during periods of high flood) is so immense when compared with the area of the river channels alone, that with this addition of 650,000,000 cubic feet spread over this vast surface, it is very questionable if it would have noticeably affected the water level of the rivers.

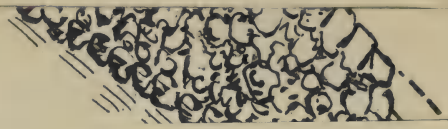
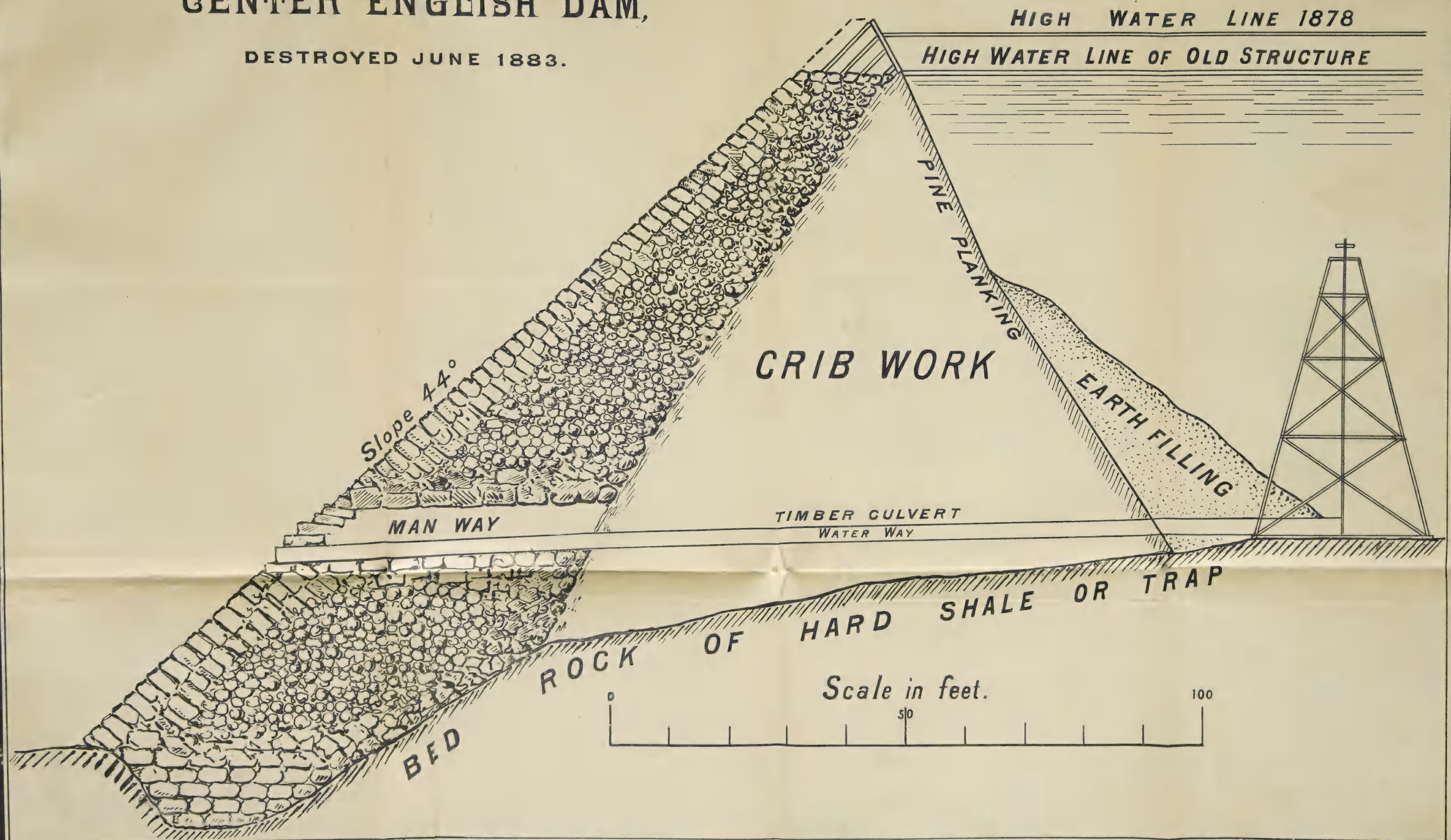


Plate No. 1.
Trans. Tech. Soc. of P.C.
VOL. II. No. XI
BOWIE ON
Destruction of English Dam.

SKETCH OF

CENTER ENGLISH DAM,

DESTROYED JUNE 1883.



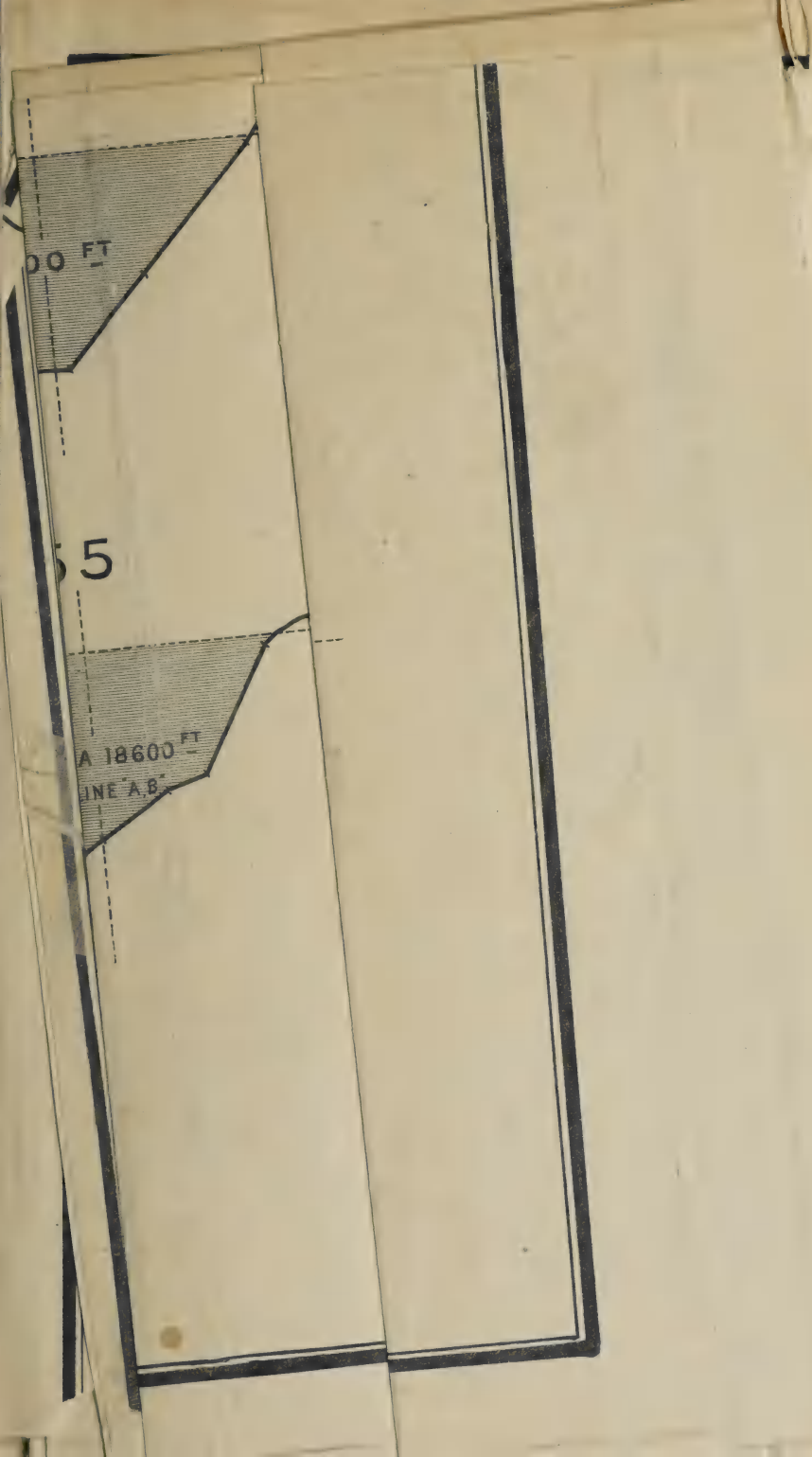

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Plate No. II
Trans. Tech. Soc. of P.C.
VOL. II No. XI.
BOWIE ON
Destruction of English Dam.

M.M.& W. Co

Cross Sections in Cañon at and below the site of the Old English Dam, destroyed June 18, 1883. From Surveys for the Construction of a New Dam, made in September 1884. by Sanford Robinson, C.E. Accompanying plan and profile of said Cañon. SCALE; 100 Feet to One Inch.
The Horizontal Dotted Line is High Water Mark of Old Dam being 87.25 FT. on Water Gauge and is datum line of the plan.

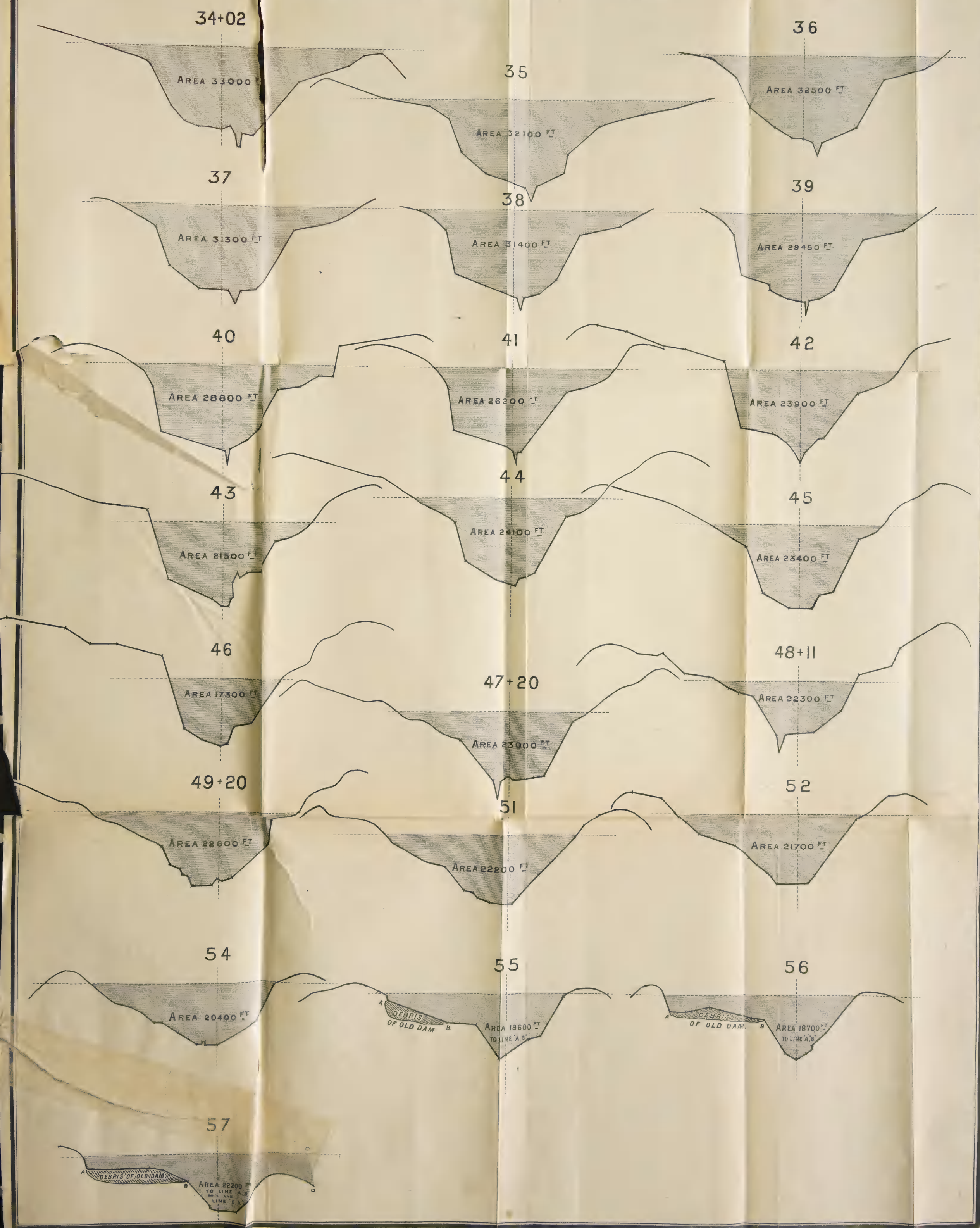

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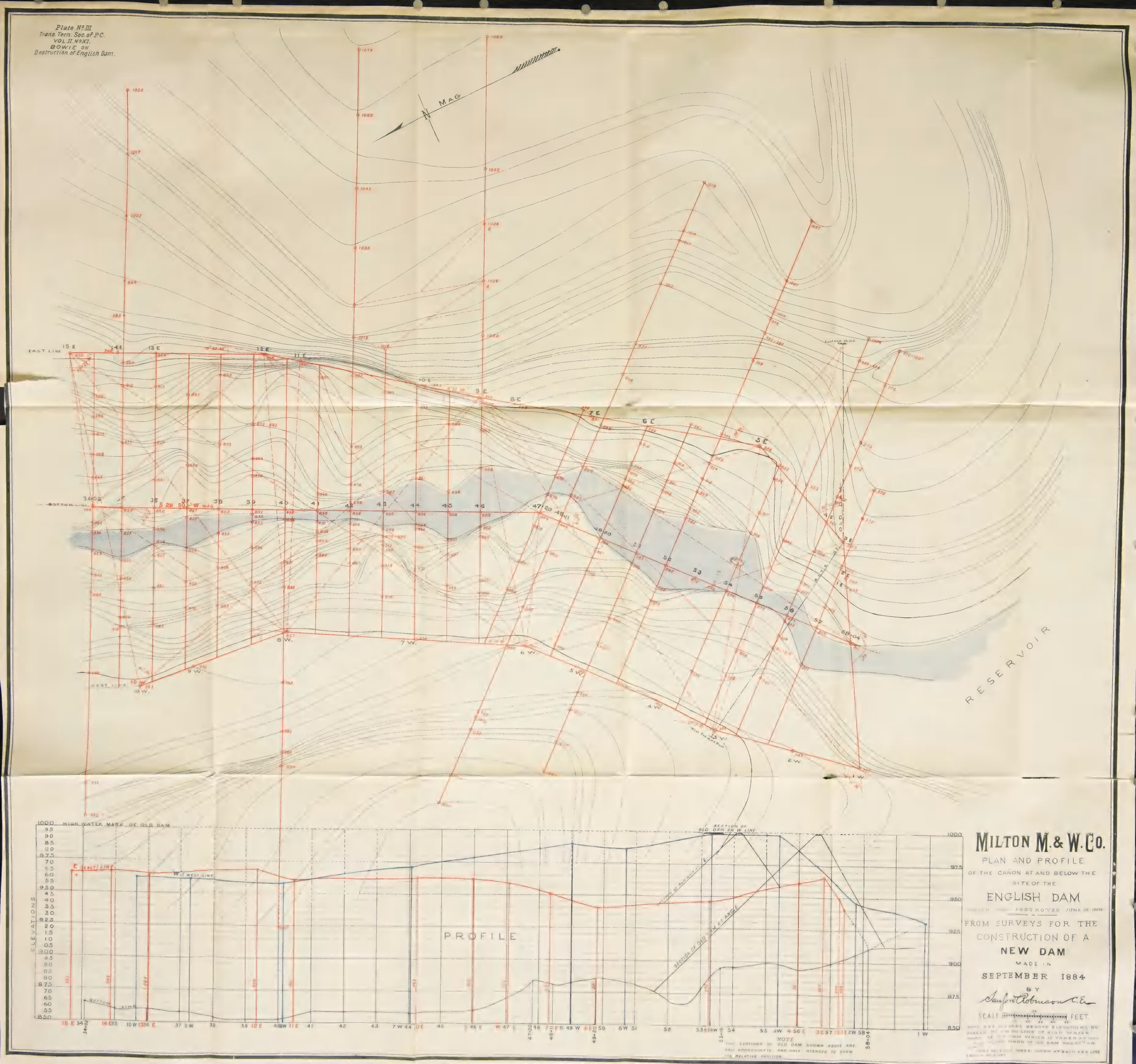
Plate No. III
Trans. Tech. Soc. of P.C.
VOL. II. No. XI.
BOWIE ON
Destruction of English Dam.



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XII.

(VOLUME II.—JANUARY, 1885.)

JOHN REYNOLDS' PROCESS OF BAR-REFINING.

By FR. GUTZKOW, Mem. Tech. Soc.

Read January 4, 1885.

In the notes of a metallurgist travelling in North America, which were published in one of the late numbers of the *Berg-und Huettenmœn-nische Zeitung*, there appears the following comment: "In refining gold and silver, people here claim to have found by experience that silver dissolves more easily in bars than in grains, an assertion which surely requires very much further testimony before it can be accepted."

This evidently has reference to the process of bar-refining invented by John Reynolds of this city in 1865, by means of which as much silver has been parted as Germany has produced during the century.

As Mr. Reynold's process is not generally known, it does not appear too late even at this date to secure to him the recognition, here and abroad, which he deserves; and in no way can the value of his invention be shown to better advantage than by giving its history.

In 1802, d'Arcet, a Frenchman, discovered the method of separating silver and gold by means of sulphuric acid. He started a refinery at Paris where he succeeded for a long time in keeping

his process a secret. Percy, in the original and humorous style which makes his books, aside from their metallurgical value, such pleasant reading, describes how, "more than twenty-five years later, the officers of the London mint, suspecting that the French had a better process of refining than their own, ordered one of their employés on detective duty; "how the detective detected not the process itself, but the very next best to it, to wit: a French workman who had been discharged by d'Arcet." With the information thus obtained, the English Government built a refinery, and prepared to work the "importation." Instead of imparting the knowledge of the working of the French process to his employers, the mint detective preserved the secret, became master of the situation, and worked the refinery on his own terms. The process finally leaked out, but every new establishment felt it to be a sacred duty to prevent further publicity, and even to this day, it is almost impossible for a chemist to get access to a Paris or London refinery. The principal secret left is what remains unknown to many a man to his dying hour, namely, cleanliness. The value of the material makes the process a chemical analysis on a large scale, where all waste must be avoided, and every by-product rapidly and completely utilized. Formerly, every part of d'Arcet's process was strictly guarded. One of the principal and most important manipulations was the granulation of the silver before parting, that is, melting and pouring it in a thin stream into cold and violently agitated water, where it would assume a shape resembling the familiar "pop-corn." The finer the granulation, the more readily did the bullion appear to dissolve; in fact, in order to prevent excessive foaming by the escaping sulphurous gas, d'Arcet was obliged to melt a certain amount, say eight or ten per cent. of copper, with the bullion, if it was of a high grade, copper being much less rapidly dissolved by sulphuric acid than silver. Unfortunately, there was a very serious drawback in d'Arcet's process. The gold as separated from the granulated silver doré was never mint-fine, that is, it never contains fully 99 per cent. of pure gold. Even if boiling in acid be ever so often repeated, it is never more than 970 or 980 fine. Pettenkofer, a German refiner, succeeded in removing the last obstinately remaining percentage of silver, by

melting the refined gold with bisulphate of potash. This operation being, however, troublesome, it remained the general practice with the refiners of the whole world to re-melt the gold obtained from the first refining and "quartate" it with silver and copper into an alloy very rich in gold, granulate and separate therefrom the gold in proper fineness by a second refining with acid.

Thus the matter stood until 1865. At that time, Reynolds had charge of the refining pots in the San Francisco refinery of the old firm of Kellogg, Hewston & Co., of which the writer was superintendent. The nervous "hurry-hurry," so characteristic of California work in all its branches, was nowhere better exemplified than in that refinery. Interest being high and coin scarce, it was of the greatest importance to the firm's customers to get their gold to the mint before the close of business-hours, or ahead of other depositors. Consequently, the refiners were hurried up by the press-men who were waiting to do their share of the joint work; these again by the melters, and long before the latter had finished, the impatient town-office had already dispatched the express-wagon for the gold bars, which went aboard much too hot to be handled without gloves, an excellent safeguard against any attempted robbery in that sparsely settled district where the refinery was situated. At the Montgomery street office-door, the assayers were all ready on the lookout for the chips, and between them and the clerks, the porters and the express-horse, the general hurry was continued until the bars were lodged at the mint, and the "agony was over."

John Reynolds was disgusted with his share in the general race. He also wanted to drive something or somebody, but the only possible object of his "furor Californicus," his refining pots, had to be heated very gently with carefully regulated fire; otherwise, the acid would foam over the pot, and not only spoil his clothes but also his reputation as a refiner. He wanted the superintendent to stop granulating altogether and give him the bars just as they came from the assay office. "I do not like those fellows," he said, "to stand around here and ask every five minutes if I am done, and I to have to throw water on the fire to keep the working down. I want to hold the fire as hot as I can from beginning to end, and I can do so only if I have all along

the same surface of metal to work upon. Never mind, if the surface is small; boiling acid dissolves ten times more silver in an hour than when it is only warm, and the more you break up the silver by granulation, the smaller the gas-bubbles and the more foaming. And if the gold is not covered by granulated silver, it will shrink together and be heavy, and if it is set free by actually boiling acid, it will be fine gold at once."

Reynolds got his bars, and since that day not an ounce of silver doré has been granulated.

In four hours, in one pot, three thousand ounces, or two hundred pounds, of unrefined bars were dissolved, against two thousand ounces, or 135 pounds, of granulation. The gold turned out 996 fine against 970 as formerly, and it separated in heavy grains of the size and shape of unboiled rice, whilst previously it was a powder which required much attention to keep it from floating into the silver in the succeeding operation. Formerly the powdery gold retained sulphate of silver so obstinately that a second boiling in acid was necessary. Now, as soon as the silver solution was bailed off, the gold could be thrown into water. The gold was ready to leave the refinery in six hours after the bars were received; when regranulated and refined by quartation a second time, it took at least fifteen hours. The new process did not cost a cent, and the only drawback was that the gold was occasionally brittle from the presence of lead, if the bars were inferior. This was easily overcome by an improvement of the writer, by which in toughening gold the costly and dangerous corrosive sublimate was supplanted by the cheap and harmless sal-ammonia, in connection with a weak air-blast playing on the surface of the molten gold. The stronger heat in refining carried more silver with the fumes into the condenser, but there was no trouble in fully recovering it.

To make this description of Reynolds' process complete, a few words have only to be added. Its greatest value is, of course, in refining bullion, like that from the Comstock Lode, which contains considerable gold. The limit seems to be twenty per cent. of gold. For silver which holds only a trifle of gold when it is of little consequence whether the gold is fine or not, there is also a great advantage in the saving of the granulation, the

larger capacity of the refining pots and the greater heaviness of the particles of gold. For the sake of uniform working, each pot ought to receive bars of tolerably equal size. Regarding the percentage of copper, there is no trouble in working bars up to fifteen per cent. of copper. When this percentage is larger, bars as well as granulations cease working, owing to the separation of insoluble copper-salts.

There is no doubt that d'Arcet, before he invented the granulation with the long train of operations which yielded him finally fine gold, likewise endeavored to part bullion in bars or coin. If his men in 1802 had been working with the same energy as Reynolds did in 1865, his successors would have saved much money. For 63 years none of them thought it possible to dispense with granulation, or, if they did think so, they certainly did not dispense with it.

Reynolds obtained a patent, but not being quite aware in what the novelty consisted, put too much weight in his specification on the novelty of refining in bars. Other refiners conveniently judged that there could be nothing new in that, and when they found in Kerl's Metallurgy a note that somewhere in Hungary they occasionally placed the silver into the refining pot in "Planchen oder Zainen" — that is, in plates or strips — dissolving them in "from 18 to 20 hours," they did not deign even to notice Reynolds' reclamations. The greatest infringement was made by the grantor of the patent, the United States Government, at its mint in San Francisco. Reynolds finally brought suit in the U. S. Circuit Court before Judge Sawyer, and in 1883 obtained a judgment against the United States Government for $52,000, it being proven that the real invention of John Reynolds was the discovery that when silver doré is refined in bars at a high temperature the resulting gold is fine gold, that this discovery was entirely unknown, and was the greatest advance in gold refining since d'Arcet made his invention in 1802.

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XIII.

(VOLUME II.—JANUARY, 1885.)

DISCUSSION ON

THE CAUSES OF EXPLOSIONS IN THE MANUFACTURE OF HIGH EXPOSIVES.*

DISCUSSION BY AUG. J. BOWIE, JR., F. H. JENSSEN, GEO. SPECHT, L. WAGONER AND J. D. SCHUYLER.

MR. AUG. J. BOWIE, JR., M. Tech. Soc.—Dr. Jenssen, I would like to ask you a few questions in relation to the manufacture of these dynamite compounds. Is there any generally acknowledged or adopted classification of dynamite compounds according to the percentage of nitro-glycerine that they contain?

MR. F. H. JENSSEN, M. Tech. Soc.—There is a general classification adopted in Europe: dynamite No. 1 is a mixture of 70 to 78 per cent, of nitro-glycerine, with an inert absorbent; gelatine dynamite No. 1 is a mixture of explosive gelatine, nitro-glycerine and dope, containing 60 to 65 per cent. nitro-glycerine, and is equal in strength to dynamite No. 1. No. 2 contains 45 to 50 per cent. nitro-glycerine, and No. 3, 20 to 30 per cent. This latter grade is but little used in Europe and a standard is not

* Paper by FRED. H. JENSSEN, M. Tech. Soc., No. X, Vol. I, page 200 (December, 1884.)

adopted for it. On this Coast no standard exists, although the same classification used in Europe is generally followed with accessory grades A, B, C and others. The so-called No. 1 here contains from 45 to 75 per cent. of nitro-glycerine; No. 2 from 25 to 50 per cent., and No. 3 from 15 to 30 per cent. of nitro-glycerine. The prices of certain grades of powder largely regulate the amount of nitro-glycerine which the manufacturers use in the compounds, and you may get a No. 1 which only equals No. 2 in strength, and a No. 2 which only equals No. 3.

Mr. Bowie.—The nitro-glycerine is compounded, as I understand it, with two classes of substances, one of them being an inert material, and the other a substance which develops gases by the explosion of the nitro-glycerine. Am I correct? And if so, please state what are the substances so used.

Dr. Jenssen—In reply to your question, I will say that the principal inert materials used as absorbents are infusorial earth, carbonate of lime or magnesia, and mica. Those which develop gases are mixtures composed chiefly of wood pulp, saw-dust, or coal with nitrate of potash or soda, and sometimes sulphur is added, but not often. The general idea is to combine a material containing carbon with one which has an abundance of oxygen, so that the heat which is generated by the explosion of nitro-glycerine produces carbonic acid and nitrogen, if nitrate is used. There are many other combinations, but those I have named are manufactured most extensively.

Mr. Bowie.—You mention danger from stirring the nitro-glycerine and acid. Is the mixture stirred violently or gently? How do you regulate it?

Dr. Jenssen—The stirring of small quantities can be done gently. Stirring by hand with a stick of lead, iron or glass is sufficient; but with larger quantities more energetic stirring is necessary, although I do not think I could call it violent. Personally, I prefer a strong stirring, as I generally work with large quantities, and an energetic stirring does not do any harm, but insures immediately the glycerine's being mixed with the acids.

Mr. Bowie.—How is the stirring done?

Dr. Jenssen—The stirring is done in different ways. In small works, as I have said before, often by hand; in larger works by means of iron wings or screws, driven by hand or by means of machine power, or with the assistance of compressed air blown through the acids.

Mr. Bowie.—Has the point been reached in the manufacture that all danger in stirring is averted?

Dr. Jenssen—In the manufacture of nitro-glycerine in the mixer, in my opinion, it has been reached, as all the circumstances and conditions which can arise have been studied so thoroughly that every danger can be virtually averted, although I cannot deny that a great many people consider this the most dangerous part of the work, but with proper arrangements, which, of course, must be complete in every respect, I feel entirely safe in this stage of the manufacture, and in fact I have never met with an accident here.

Mr. Bowie.—Apropos of the danger you mention as existing in the process of regaining the excess of acid from the nitroglycerine is that not due to the decomposition of the acid nitroglycerine?

Dr. Jenssen—Yes, there is danger in regaining the excess of acids by whatever method you may employ, which is due to the easy decomposition and the great sensitiveness of the acid nitroglycerine.

Mr. Bowie.—You say that there is no danger in the mixing house? How do you account for the explosions which have occurred in such places?

Dr. Jenssen—I think that most of the explosions which have taken place in the mixing departments are attributable to the carelessness of the workmen, although some mistakes in the construction of the mixing houses can be made apart from the arrangements for heating which have been mentioned. You may find the floors made of cement or bricks, or if of wood, with

the heads of iron nails sometimes protruding. The spilling of small quantities of powder on the floor during the work cannot be well avoided, and a man with iron nails in his boots, stepping on this material, can easily cause sufficient friction or shock to start an explosion. Accidents are known to have arisen from such causes.

Mr. Bowie.—To what extent is heat required, coming from sunbeams, to decompose the nitro-glycerine, and is there an oxidation of the nitro-glycerine caused by the direct rays of the sun?

Dr. Jenssen—I cannot give you the exact degree of heat required to increase the decomposition of acid nitro-glycerine. A slow decomposition is continuously going on in the nitro-glycerine so long as it contains nitrous or hyponitric acid, but about 120° Fahrenheit will start a very rapid decomposition of the acid nitro-glycerine. During the winter I have had the sun shining for a day on acid nitro-glycerine without finding much change, but in the summer time a strong and marked decomposition can be sometimes noted in less than an hour. When I mentioned that the windows should be provided with curtains or some other shelter to keep the sun off, I did not allude directly to the fact of the chemical decomposition produced by sunbeams on neutral nitro-glycerine, although the heat of the sun increases the temperature of the powder, and thus makes it more sensitive.

Mr. Bowie.—Taking 70% of nitro-glycerine, mixed with the *best known absorbent*, at how high a temperature can you rely on it to retain the nitro-glycerine? Is it safe at 100°, 110°, 120° Fahrenheit? Is it safe to carry on a boat during the summer months where it may be exposed to the heat of the sun?

Dr. Jenssen—If the nitro-glycerine is absorbed completely it will be retained at a temperature even above 120° Fahrenheit, and it is perfectly safe to transport the dynamite in a boat, or by land, at any temperature that a man can endure, although I would like to cover the boxes with a blanket for greater security, and for the purpose of protecting the wood from cracking. Of

course I am speaking only of a first class dynamite, and am not taking into consideration inferior products, the qualities of which differ most materially.

Mr. Bowie.—Suppose, as it may sometimes occur, that the dynamite contained a small amount of acid nitro-glycerine, what temperature would such dynamite stand, and would it be safe to transport exposed to the sun's rays?

Dr. Jenssen.—Acid nitro-glycerine compounds should never be allowed to leave the works. They will decompose at ordinary temperature of 60°–70° Fahr. They are extremely sensitive, and if stored one never knows how far chemical decomposition has advanced. Therefore they are very dangerous to handle, and could not be transported with any degree of safety, let alone being exposed to the heat of the sun's rays.

Mr. Bowie.—Taking the available No. 1 powder commonly obtained in American markets, does it contain any acid nitro-glycerine?

Dr. Jenssen.—So far as I am personally aware of, I can state that in my experience I have never found any dynamite for sale on this Coast which contained acid nitro-glycerine.

Mr. Bowie.—To what extent are explosions of dynamite due to shocks or jars? I have frequently observed where cartridges of dynamite failed to explode, that they were exploded subsequently when other shots were fired, although the holes for these were placed some distance off from where the *unexploded* cartridges were situated.

Dr. Jenssen.—Where I have made new bore holes for the purpose of firing charges which had failed to explode, I tried to bring the bottom of the hole for the new charge to within about six inches of the old one, and thus on firing the new charge, have always succeeded in exploding both charges. The distance at which one charge will explode another by concussion or shock communicated through rock, depends mainly upon the quantity of the charge first exploded, and likewise on the nature

of the rock. On the other hand, the stability of dynamite against shocks or jars varies with the different materials through which the concussions or shocks are communicated. Dynamite is very sensitive when placed between iron, and very little so when placed between wood.

Mr. Bowie.—How may or can shocks be communicated which will explode nitro-glycerine compounds, not referring, of course, to a direct-shock?

Dr. Jenssen.—The best and surest communication is, of course, the direct one, but as I said before, the necessary impulse can be communicated through rock, and likewise through water. The air is a poor medium, but under certain circumstances and conditions, a sufficient shock can be communicated through it so as to cause an explosion. From some personal observations I could state that with an explosion of ten tons in the open air, the shock was not communicated fifty yards. Trials under water three feet deep, on a small scale, with five pounds of No. 1, was found to communicate the shock and explode this charge to as great a distance as 25 feet, but no further.

Mr. Bowie.—How can you prevent these indirect shocks or jars being communicated to stored nitro-glycerine compounds and exploding the powder?

Dr. Jenssen.—By placing the store-houses as much as possible out of the way, or by protecting them on the side towards which you can expect shocks, by means of a dam or wall. It is a good plan never to place the boxes containing powder close against the wall of the store-house, or directly on the floor; but always to leave an open space between the wall and the powder, as likewise between it and the floor. Under ordinary circumstances, this precaution will afford the best protection against the effects from explosions which may occur in the neighborhood.

Mr. Bowie.—What proportion of the explosions at dynamite works are attributable to carelessness on the part of workmen, or is not a large proportion of accidents occurring at works

accounted for by the general ignorance of the properties of the nitro-glycerine compounds?

Mr. Jenssen.—In the first years of this new industry most of the explosions were caused by the defective arrangements of works. Experience and exact knowledge of the product manufactured had to be obtained. Therefore I would not attribute the cause of the explosions to the ignorance of technical men in charge of the works. Of late years they have become more experienced, and explosions caused by faulty arrangements are of rare occurrence. The present aim of the technical man is to lessen the chances of explosions being caused by the carelessness of workmen. This of course only refers to old established works, or new ones in charge of men of long practical experience. In new works constructed by inexperienced men, accidents due to faulty arrangements are liable to occur as frequently as they formerly did, although the general knowledge of the properties of nitro-glycerine is naturally greater since it has come into general use. It is difficult to answer your question exactly, as the proprietors of powder works keep the causes of accidents concealed from outsiders, and you can rarely find out the real causes of accidents in works other than those with which you are intimately connected.

Mr. Bowie.—I will take the liberty of asking you finally a question which may be a little outside of the general scope of your paper, namely, to what extent, or what assurances can be had that in the manufacture of nitro-glycerine compounds that the absorbent used will retain the nitro-glycerine? or is it not a fact that, under ordinary conditions, there is no known absorbent which will not at some time give up a portion of its nitro-glycerine, saturating or wetting the cartridge paper or oiling or permeating the wooden box, thus leaving you confronted directly with nitro-glycerine and its attendant dangers?

Dr. Jenssen.—Good absorbents retain the nitro-glycerine under ordinary circumstances. Often, however, poor, insufficient absorbents are used for the purpose of making the powder appear moist and to contain a larger amount of nitro-glycerine

than it in fact does. Such powder easily exudes nitro-glycerine under an increased pressure or temperature. All dynamites give up nitro-glycerine if they come in contact with water, except Nobel's explosive gelatine, gelatine dynamite and Frauzl's dynamite. The greater part of the powder manufactured on this coast contains nitrate of soda, and although the cartridge paper is saturated and coated with paraffine, wax, etc., the powder absorbs moisture from the air in wet tunnels and mines. If the powder be exposed for a longer time, it gives up a part of the nitro-glycerine, and therefore this should be especially guarded against.

Mr. Geo. J. Specht, M. Tech. Soc.—Does not explosive gelatine sometimes give up nitro-glycerine?

Dr. Jenssen.—Yes, it did; when the gelatine was first manufactured. But it should not now occur, as the method of manufacturing the necessary quality of collodion cotton is sufficiently known, so it can be prevented.

Mr. L. Wagoner, M. Tech. Soc.—How much powder is used to explode nitro-glycerine?

Dr. Jenssen.—I cannot give you the exact amount necessary. So far as I know, it is no longer used; however, I will add, 50 grammes of sporting powder confined in a zinc tube will explode nitro-glycerine without fail.

Mr. Wagoner.—In testing low grade powder, will not the cap effect the result?

Dr. Jenssen.—In testing powder, the effect of the cap must be always deducted from the result obtained.

Mr. Wagoner.—Suppose I use a triple force cap to explode 30 grains of low grade powder, would this be suitable to detonate three pounds? Must not there be some proportion between the fulminate and the charge?

Dr. Jenssen.—Low grade powders require primers of high

explosives. But the quantity of the primer depends entirely upon the quality of the low grade powder.

Mr. Wagoner.—Suppose I had a deep bore hole loaded with low grade powder and on top of this charge some high grade powder, could the high grade powder be exploded without exploding the low grade underneath?

Dr Jenssen.—Some of the low grade powder will always be exploded, but it depends entirely upon the nature of the low grade powder and the length of the charge, as to whether all the powder will be exploded. Before charging a large mine, it should be determined by experiment as to what depth of powder the primers will act with certainty.

Mr. Wagoner.—Suppose the powder becomes damp?

Dr. Jenssen.—Damp powder, high grade as well as low grade, is less sensitive than dry powder. Especially the low grade powder, which sometimes when damp can scarcely be exploded.

Mr. Wagoner.—To insure certainty then, powder should be freshly made and dry?

Dr. Jenssen.—Yes; fresh and dry powder is always preferable.

Mr. J. D. Schuyler, M. Tech. Soc.—In testing low grade powder do you use the mortar?

Dr. Jenssen.—Yes, mortar and pressure gauge; but I prefer to test it in wet clay or in a swamp, and thus be able to measure the cavity or crater from opening made. This method comes near practice, and seems to me preferable.

Mr. Schuyler.—Do they make blasting gelatine here on this Coast?

Dr. Jenssen.—I have made some here, and I understand that the Giant Powder Company is manufacturing it in small quantities. So far as I am aware, they have no arrangements for manufacturing it in large quantities.

Mr. Wagoner.—Which method is used for testing giant powder?

Dr. Jenssen.—Mostly the pressure gauge; sometimes the mortar.

Mr. Wagoner.—We have found difficulty with low-grade powders. Some, when tested with the pressure gauge, gave good results, but in practice failed. When experimented with on a small lot it detonates, but sometimes with 100 kegs or more would not detonate.

Dr. Jenssen.—I think that the principal cause of the missing shots was due to the fact that the charge was too large for the primer used, or that the powder was too slow to be exploded by one primer on top. In large blasts of 100 kegs or more, I think it is absolutely necessary to distribute some boxes of high explosives in the charge, so as to have a sufficient primer and to insure the explosion of all the powder.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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XIV.

(VOLUME II. — JANUARY, 1885.)

ADDRESS OF COL. GEORGE H. MENDELL.

GENTLEMEN OF THE TECHNICAL SOCIETY—Although not prescribed by our constitution, it is a good rule to require at the annual meeting an address which shall gather in compendious form the history of the Society during the past year, record what has been accomplished, and suggest what remains within reach for future effort.

We have as yet no history. This is yet to be made. The Society may be likened to a healthy child, struggling to put in articulate form ideas more or less completely shaped and aspirations more or less clearly conceived. The vigor of the child gives promise of achievement in the future.

Coming into life in the growing society of the Pacific Coast, living in sympathy with its progress and developed in growth by the characteristic features of its industrial advance, it may be hoped that this association will grow into a permanent body comprising within its limits a large proportion of intelligent members of society engaged in industrial pursuits, and afford by its ever-increasing advantages opportunity for improvement to all.

It is worthy of remark that increased accomplishment in our professions and the elevation and broadening which are to us the direct benefits expected from association, are to the public a more faithful and intelligent treatment of its industrial problems.

We are not, therefore, associated for our own benefit in a narrow sense. We may hope that whatever of truth may result from or be developed by our discussions will work in some degree for the benefit of the community and of the State.

The professions which are represented in this Society form in great part the advance guard of industrial progress. Although different, these professions are not independent of each other. All are engaged in the application of natural principles to the various purposes of life and at some points find themselves in contact with all others. The civil engineer and the architect may be considered as varieties of the same profession. Chemistry teaches the composition of materials which the constructing professions use and by new combinations or methods modifies, cheapens or produces new materials which substantially revolutionize construction. The mechanician facilitates the operations of all others by new devices.

Further analysis might, in the same way, exhibit relations more or less close between all the professions represented in this Society. An association of persons so related, while perhaps not possessed of the homogeneousness of a stricter classification, yet has in it sufficient elements of sympathy and harmony of purpose upon which to found a strong Society.

The additional numbers which our constitution insures ought to impart a livelier interest, while the greater variety of experience and wider range of investigation ought to serve our purpose of self-improvement in the best practicable way.

If these considerations have any weight, they go to show that the basis and principles underlying our society are sound, and that properly developed they ought to insure a prosperous future. But we must not expect too much, and particularly we must not expect too soon.

The comparatively small numbers of our population, the urgent character of the occupations of many of our members, the comparatively small opportunity for experimental observation in a new country, and other circumstances of our Western life may not permit us at once to take the position that we may ultimately expect to occupy and which the impatient may expect us to take at once.

The influence of this association upon society at large will be in proportion to our own improvement and growth. Our members are now and will be in future connected with the great steps of development of the natural interests and resources of this coast. Among these are the extension of the area of irrigation, improvement in its methods, the reclamation of its overflowed lands, the application of electricity as motors and in lighting, the improvement of our navigable channels and means of communication in general, and among the greatest the development of its mineral resources and manufactures. These are among the great interests of society. The comfort, the social and moral interests of the great mass of our people are more or less directly concerned in these operations.

It is probable that the majority of the persons who are to apply technical knowledge to the promotion of these great social ends will be members of this association, and all must necessarily be in sympathy with our intentions.

The force of a Society numbering in its members the professional actors in these great enterprises ought to have a social influence equalling that of any other body of associated professional men. Such a force judiciously exercised is capable of conferring benefits upon the public as well as upon its own members. Doubtless the future will open to view many avenues by which the general interest may be reached and its benefit secured through the influence of a strong Society. We have already taken one step in this direction. We have a committee and a report looking to accurate methods of measurement of water. As water is the essential condition of cultivation in parts of the State, as the land is large and the supply of water is limited, it must be used with care and prudence, and the first step to insure this is ability to measure it conveniently and with reasonable accuracy.

Another direction, which seems to offer an opportunity for an improvement, affecting the comfort, health and interest of the population of our cities, is connected with our municipal administrations which control the water supply, sewage and streets. It is needless, and perhaps not entirely appropriate here, to say much of the defects and condition of the pavements and sewers

of some of our cities. It does no harm to say, what everyone knows, that in some of our large cities there is, and has been, no system in these important matters. In consequence the administration is expensive, and as there is no special responsibility the results are particularly bad.

The form of remedy would be easy to indicate if our political system, as practically illustrated by existing methods, permitted it to be carried out. To give responsibility there must be a single person to bear it. To give efficiency he must be a professional man with certain defined qualities. To insure the choice of such a person it seems to be essential, in large cities at least, that he shall not be elected as city officers in general are chosen.

The class of persons suitable for such a responsibility are not those whom the managers of our political parties who give us the names we are to accept, are likely to look upon with favor. By the very elements of character and by mode of life, this class of men are not politicians, and, perhaps, not even popular—that is, not personally known to any large proportion of voters. The character of the responsibility and the permanence of an adopted system, which it is desirable to fix, are inconsistent with a tenure of office of a year or two.

Perhaps it may turn out that the dissemination of information emanating from this Society will, in the future, lead to a clearer conception by the people of the wastefulness, discomfort and danger of absence of system and adequate responsibility, and, following this, the adoption of appropriate methods of remedy.

Nothing contributes more to the comfort and well-being of a metropolitan population than good streets and a well-adjusted system of sewerage. This condition, combined with an efficient and economical administration, is attainable, and if secured, would go far to console us for many of the inevitable ills of life.

It must happen that subjects of much public interest will be professionally discussed in our papers. The facts and conditions will be made known, and it can hardly fail that suggestions of value will be made and be followed more or less to the advantage of every one.

Individual improvement and accomplishment set forth in our constitution as objects are sufficient to justify the existence of

the Society. If, in addition, we prove to be able to influence communities to their benefit, we certainly have an incontestable *raison d'être.*

The members of this Society are to be congratulated upon its present prospects. Less than a year old, the Society has now 137 members. These are drawn from all, or nearly all, the industrial professions, represented on the Pacific Coast. A number of interesting and creditable papers have been read and published, and we have the promise of others for the future. Here perhaps it is well enough to remark the desirability of having on hand several papers in advance. There cannot well be too many papers in reserve. It may happen that without a reserve the Executive Committee charged by the constitution with the duty of examining the papers before adopting them, may not have the opportunity to give the careful attention to this subject which is desirable. This point is here mentioned in order that members having papers in preparation may be moved to send them to the Secretary as soon as they are prepared. Under this system there ought always to be at least one or two examined papers on hand. In this way disappointment by failure to have one for each meeting will be avoided.

The interest felt in the Society must be shown by attendance on its regular meetings, by prompt payment of the prescribed dues, and by offerings of papers. These acts represent the duties of members, and as these duties shall be performed so will be the measure of our prosperity. If, however, we have papers upon professional subjects in due supply, we may be sure of reasonable attendance and of pecuniary support. It is, therefore, specially the duty of all who have our success at heart to exert themselves to prepare papers. These and the discussions which they may elicit are the permanent record of our operations and our means of improvement.

In the matter of election of the Board of Direction, it is worthy of consideration whether our constitution ought not to provide for a yearly change of a certain number of Directors. With the present number of Directors a regular system of rotation is hardly practicable, but if the number were made nine instead of

seven, it might be provided, if thought desirable, that one-third retire each year.

To provide for cases of absence of the President and Vice-President, it seems desirable to have two Vice-Presidents instead of one as now.

The constitution permits the re-election of the President for any number of successive terms of one year each. The office comes thus each year within the control of the Society, but it may be a question whether it is not desirable to limit the tenure to one or two successive terms.

I have to thank you for the much appreciated honor of the office of President bestowed upon me by your votes at the organization of this Society. If my ability to serve the Society were proportionate to my good will and interest in its success, I would feel entirely satisfied, and I would hope that you would be equally content. But organized as this Society is, its welfare is not in the hands of any single individual. Its health and progress must depend primarily upon the efforts of its members, and much upon the interest shown and felt by the Board of Direction.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME II. — JANUARY, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

January 4, 1885.

Vice-President Specht in the Chair.

Minutes of preceding meeting read and approved.

Hermann Krusi was proposed for membership by W. H. Smyth, Emil Adler and Marsden Manson.

Aug. J. Bowie, Jr., read a paper "On the Destruction of the English Dam."

Mr. Fr. Gutzkow read a paper on John Reynolds' Process of Bar Refining.

Mr. Bowie, of the Committee on Measurement of Water, presented a written report from the committee, in which it was recommended that they be allowed to memorialize the Legislature on behalf of the Society on the subject of establishing an unit for the measurement of water in this State.

On motion of Mr. Manson, the committee was continued and requested to memorialize the Legislature as suggested.

The Nominating Committee reported the following regular ticket:

President, G. H. Mendell; Vice-President, Geo. J. Specht; Secretary, Chas. G. Yale; Treasurer, G. W. Percy. Board of Direction—Seth Babson (architect), Fr. Gutzkow (chemist), J. D. Schuyler (civil engineer), Aug. J. Bowie, Jr., (mining engineer) G. W. Dickie (mechanical engineer).

A report from the Finance Committee was presented and discussed.

Messrs. Gutzkow and Jenssen were appointed Inspectors of Election, and Messrs. Wagoner and Behr, Judges of Election.

A discussion ensued on Mr. Jenssen's paper on Causes of Explosions in Manufacture of High Explosives.

ANNUAL MEETING.

January 16, 1885.

President Mendell in the Chair.

The President read his annual address. (See page 26.)

The Treasurer submitted a statement of accounts for the past year.

The report of the Board of Direction was read by the Secretary.

San Francisco, January 16, 1885.

To the Members of the Technical Society of the Pacific Coast:

Gentlemen—In accordance with the terms of the constitution, the Board of Direction of the Society desire to present a report for the past year, and an estimate of the expenses for the coming one.

The Society was fully organized in April, and when the constitution, by-laws and list of members was printed, there were on the rolls 119 members. Since that time 21 more members have joined. We have lost one member by death and two have resigned. We have now on the rolls 116 resident members and 21 non-resident members, a total of 137 members.

The Treasurer's report, which forms a portion of this, will give you the details of receipts and expenditures for the past year. We desire more particularly to call your attention to the sources of expenditure.

We have expended the following sums:

Rent Druids' Hall	$160 00
Salary of Secretary	225 00
Engraving and lithographing	234 75
Stationery, books and stamps	41 00
Circulars, postals, notices, etc	104 45
Constitution and By-Laws	40 00
Commissions on collections	22 50
Printing transactions	384 50

It will be seen that the total for printing has been $528.95, of which $384.50 was for transactions of the Society. The engraving bill should be properly added to this last item to get at the cost of the transactions. This will make the total cost of the transactions $629.25, the remainder of the bills for printing having been due to the necessary circulars, etc., in organizing and conducting the Society, blanks, postals, notices of meetings, circulars, etc.

Having at this date 116 resident members, who pay $12 per year, or $1,392, and 21 non-resident members, who pay $6 per year, or $126, we find our total income will be no more than $1,518 for the ensuing year. This, of course, takes no account of possible loss of members, neither is an increase of membership considered. It is believed, however, that, now the Society s fairly started, we shall enroll a number of new members this year. It must be remembered that the initiation fees of all the members were collected last year, a source of revenue which we will not have in 1885.

Taking these figures as a basis, the Board of Direction submits the following estimate of expenses for 1885:

Rent	$240 00
Salary of Secretary	300 00
Postage, etc	50 00
Stationery, etc	10 00
Collecting	40 00
Total	$640 00

This would leave the Society the sum of $878 for printing and engraving, which is none too much, in view of the fact that last

year our printing and engraving for transactions alone amounted to $629.25 for the nine months the Society has been in existence. All the necessary blanks have been printed and paid for, and there are plenty on hand. But from this amount estimated for printing, a portion will have to be expended in sending out circulars, postal cards, notices, etc., so that no more than $800 of the $878 will be available for the transactions.

We recognize the fact that the life of a society of this kind depends largely on the publication of its transactions promptly. Several papers are now being prepared, but should we cease printing this would not be the case, and the members would lose interest.

We are, therefore, of the opinion that the proposed reduction of dues is at this time unwise, although it may be done when our membership is increased. Were the dues reduced as proposed, the income from resident members would be but $928 instead of $1,392, and of non-resident, $84 in place of $126, a reduction on the aggregate from $1,518 to $1,012. Deducting the necessary expenses, aside from printing, on this basis of income, we should have only the sum of $372 to print circulars, transactions, make engravings, etc., which would be entirely inadequate.

The Board of Direction is of the opinion that the Society is now on a prosperous basis and prospects of steady growth, and would recommend that no radical changes in its laws and rules be made at this time.

We have published five numbers of Volume 1, aggregating 210 pages, of the transactions of the Society, and No. 1 of Volume 2 is in press.

On motion, Article XIX of the Constitution was changed by altering the word Saturday in the fifth line to the word Friday.

The amendment to Article VII of the By-Laws, offered by Mr. Hanscom at the meeting of November 7th, was read.

On motion, it was resolved to maintain the yearly dues at the same rate as for the past year, so that the amendment to Article VII, which changed the rate, was not carried.

The Judges and Inspectors of Election presented a report, stating that 41 votes were cast, resulting in the election of the following officers for 1885:

President, Col. Geo. H. Mendell; Vice-President, Geo. J. Specht; Secretary, Chas. G. Yale; Treasurer, Geo. W. Percy. Board of Direction—Seth Babson, Fr. Gutzkow, J. D. Schuyler, Aug. J. Bowie, Jr., Geo. W. Dickie.

On motion, a vote of thanks was passed to Mr. J. B. Crockett, for services rendered to the Society while Treasurer.

On motion of Mr. Bowie, it was resolved to print the annual address of the President, and the report of the Board of Direction in the transactions of the Society.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

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XV.

(VOLUME II —FEBRUARY, 1885.)

HYDRAULIC TABLES BASED ON THE FORMULÆ OF D'ARCY AND KUTTER.

By P. J. FLYNN, Mem. Tech. Soc.

Read February 6, 1885.

The object of this paper is to show how the work of computation required for the solution of problems in hydraulic engineering is very much diminished by the use of the following tables. It is believed that these tables will be of material help to hydraulic engineers who make it a practice to use the formulæ of D'Arcy and Kutter in the solution of problems relating to pipes for the flow of water.

In the following formulæ let—

V = velocity in feet per second.

Q = discharge in cubic feet per second.

C = coëfficient of mean velocity.

S = fall of water surface (h), in any distance (l), divided by that distance $= \frac{h}{l}$ = sine of slope.

a = area of cross section of pipe or conduit in square feet.

p = wetted perimeter of pipe or conduit in lineal feet.

$r =$ hydraulic mean depth in feet $=$ area of cross section of pipe or conduit in square feet (a) divided by its wetted perimeter in lineal feet $p = \frac{a}{p}$

$d =$ diameter of pipe or conduit.

$n =$ the natural coëfficient, the value of which depends on the nature and condition of the bed of the channel through which the water flows, or in other words its degree of roughness.

The plan on which the tables are constructed will be briefly stated here and their use will be more fully explained at the end of the paper.

Chezy's general form of formula for velocity is—

$$V = c\sqrt{rs} = c\sqrt{r} \times \sqrt{s}$$

therefore $$Q = a\,c\sqrt{rs} = a\,c\sqrt{r} \times \sqrt{s}$$

The factors on the right hand side of the equations are tabulated: $c\sqrt{r}$ and $a\,c\sqrt{r}$ for diameters usually adopted in practice, and $\sqrt{s}$ for several slopes.

Now to find the velocity, the diameter and slope being given. Look out and note down the number representing $c\sqrt{r}$ in its column and opposite the given diameter; also look out and note down the number representing $\sqrt{s}$ opposite the given slope. The product of these two numbers will give the required velocity. Again given the slope and velocity in feet per second to find the diameter. From the equation

$$V = c\sqrt{r} \times \sqrt{s}$$

we have $$c\sqrt{r} = \frac{V}{\sqrt{s}}$$

Look out the value of $\sqrt{s}$ corresponding to the given slope and divide the velocity by it. The quotient will be the value of $c\sqrt{r}$. In the column of $c\sqrt{r}$ look out the nearest number to the value of $c\sqrt{r}$ so found, and opposite to it in the same line will be the diameter required. At the same time the area and hydraulic mean depth can be found on the same line and the discharge can be found by looking out the value of $a\,c\sqrt{r}$ and dividing it by $\sqrt{s}$. In fact by inspection of the tables and the

multiplication or division of two numbers, problems can be rapidly and accurately solved, which, by the use of any one of the formulæ would be a tedious and troublesome operation. When the value of $c\sqrt{r}$ or $a\,c\sqrt{r}$ is found the diameter can at once be found by inspection.

When the slope and velocity are given and the diameter is required it is not found directly. The value of $c\sqrt{r}$ is first computed by formula (10) and in the same line with this value in the tables will be found the required diameter. In a similar way the slope and discharge being given and the diameter required. The value of $a\,c\sqrt{r}$ is first computed by formular (15) and in the same line with this value in the tables will be found the required diameter.

The columns of $c\sqrt{r}$ and $a\,c\sqrt{r}$ can be used to compare velocities and discharges of pipes with equal slopes, and this can be done even when the channels have different degrees of roughness if the tables have been prepared from the same formula.

For instance, a pipe say of 3 feet diameter has a discharge of 20 c. feet per second by D'Arcy's formula, and it is required to find the diameter of a pipe which shall discharge 30 c. feet per second, that is an increase of 50 per cent., the slope being the same in both pipes. Find in table 1 the value of $a\,c\sqrt{r}$ opposite 3 feet diameter and it is = 674.09, and this increased by 50 per cent. = 1011.1 = the value of $a\,c\sqrt{r}$ corresponding to the required diameter. By inspection of table 1 the nearest value of $a\,c\sqrt{r}$ to this is found to be 1021.1 opposite a diameter of 3 feet 6 inches, which is the required diameter. In a similar manner velocities can be compared by the use of the column giving the values of $c\sqrt{r}$.

For feet measures D'Arcy's formula is—

$$V = \left(\frac{r\,s}{.00007726 + \frac{.00000162}{r}}\right)^{\frac{1}{2}} \qquad (1)$$

and from this we have

$$S = \left(.00007726 + \frac{.00000162}{r}\right)\frac{V^2}{r} \qquad (2)$$

In order to simplify, *substitute for r in feet the diameter d in inches*, and we have—

$$S = \left(.00007726 + \frac{.00000162 \times 48}{d}\right)\frac{48\ V^2}{d}$$

$$\therefore\quad S = \left(\ .00370848\ d + .00373248\ \right)\frac{V^2}{d^2}$$

As the change will not materially affect the result, Mr. J. B. Francis, C. E., simplifies this into the form—

$$S = .00371\left(d + 1\right)\frac{V^2}{d^2} \qquad (3)$$

$$\therefore\quad V = \left[\frac{S\ d^2}{.00371\ (d + 1)}\right]^{\frac{1}{2}} \qquad (4)$$

In order, however, to further simplify the equation into the Chezy form of formula, which is the form required for the preparation and use of the table adopted by the writer, and given at the end of this paper, let equation (3) be transformed into one with the *diameter d in feet* and it becomes—

$$S = .00371\ \left(12\ d + 1\right)\frac{V^2}{144\ d^2}$$

$$\therefore\quad V = \left[\frac{144\ d^2\ S}{.00371\ (12\ d + 1)}\right]^{\frac{1}{2}}$$

but $d^2 = 16\ r^2 = 16\ r \times r = 4\ d \times r$ substitute this value for d^2 in the last equation, and—

$$V = \left[\frac{144 \times 4\ d \times r \times S}{.00371\ (12\ d + 1)}\right]^{\frac{1}{2}}$$

therefore, *for feet measures* D'Arcy's formula for velocity is simplified into—

$$V = \left(\frac{155256\ d}{12\ d + 1}\right)^{\frac{1}{2}} \times \sqrt{r\,s} \qquad (5)$$

and putting the first factor on the right hand side of the equation $= c$, we have—

$$V = c\sqrt{r\,s} = c\sqrt{r} \times \sqrt{s}$$

Kutter's formula for feet measures is—

$$V = \left[\frac{41.6 + \frac{1.811}{n} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right) \frac{n}{\sqrt{r}}} \right] \times \sqrt{rs} \qquad (6)$$

and putting the first factor on the right hand side of the equation $= c$ we have—

$$V = c\sqrt{rs} = c\sqrt{r} \times \sqrt{s}$$

In the solution of problems relating to pipes, of diameters different from those given in the tables, Kutter's formula (6) can be simplified in form by adopting it to a slope of 1 in 1,000. It then becomes when $n = .013$—

$$V = \left\{ \frac{183.72}{1 + \left(44.41 \times \frac{n}{\sqrt{r}}\right)} \right\} \times \sqrt{rs} \qquad (7)$$

and when $n = .011$

$$V = \left\{ \frac{209.05}{1 + \left(44.41 \times \frac{n}{\sqrt{r}}\right)} \right\} \times \sqrt{rs} \qquad (8)$$

The velocity by these formulæ will be near enough to the true velocity for all practical purposes. The difference between the result found and the true velocity will be about the same amount for the same diameter as that shown in tables 7 and 8.

As shown above the general form of the formulæ of D'Arcy and Kutter is—

$$V = c\sqrt{r} \times \sqrt{s} \qquad (9)$$

$$\therefore\ c\sqrt{r} = \frac{V}{\sqrt{s}} \qquad (10)$$

$$\sqrt{s} = \frac{V}{c\sqrt{r}} \qquad (11)$$

$$S = \left(\frac{V}{c\sqrt{r}}\right)^2 \qquad (12)$$

Now $$Q = a\,V = a\,c\sqrt{r} \times \sqrt{s} \qquad (13)$$

$$\therefore\ a = \frac{Q}{v} \qquad (14)$$

$$a\,c\sqrt{r} = \frac{Q}{\sqrt{s}} \qquad (15)$$

$$\sqrt{s} = \frac{Q}{a\,c\sqrt{r}} \qquad (16)$$

$$\left(\frac{Q}{a\,c\sqrt{r}}\right) \qquad (17)$$

By the use of the tables of factors as applied to the solution of the six formulæ (9) (10) (11) (13) (15) (16) all the information relative to pipes, such as velocity, slope, etc., can be obtained.

Kutter gives for the values of the natural coëfficient of surface—

$n = .010$ Plaster in pure cement.
$n = .011$ Plaster in cement with one-third sand.
$n = .013$ Ashlar and brickwork.

Mr. Lewis D'A. Jackson, C. E., who first translated the work of Kutter into English, and who in his *Hydraulic Manual* and other contributions to the literature of hydraulic engineering, has done so much to introduce the new and improved hydraulic formulæ into English and American practice, extends the range of surfaces to which the above values of n apply.

In his *Hydraulic Manual* he states that—

"A coëfficient of roughness $n = .010$ has been assumed as "applicable to glazed or enamelled pipes, and one of .013 for "ordinary metal or earthenware or stoneware pipes under ordin-"ary conditions, but not new; and there is every reason to be-"lieve that these assumptions are generally correct; if we com-"pare the smoothness of surface of a glazed pipe with that of "very smooth plaster in cement, and that of an ordinary pipe, "in average condition with that of ashlar or good brickwork; in "addition to this, such few partial and limited experimental "data as are available support the assumption."

Mr. R. Hering, C. E., in a paper read before the Am. Soc. C. E., in 1868, gave a list of pipes of different materials whose surfaces closely approximate in roughness to the surfaces included by Kutter's coëfficients $n = .011$, and $n = .013$.

In this paper the coëfficients of Jackson and Hering have been adopted, and table 2 gives $n = .011$ for surfaces carefully plastered with cement with one-third sand in good condition, also for iron, cement and terra cotta pipes, well jointed, and in best order, and also surfaces of other material equally rough. Table 3 assumes that $n = .013$ for ashlar, well laid brickwork, ordinary metal, earthenware and stoneware pipes, but not new, cement and terra cotta pipes not well jointed nor in perfect order, plaster and planed wood in imperfect or inferior condition, and also surfaces of other material equally rough.

In table 5 the coëfficients c of D'Arcy, and Kutter with $n = .011$ for smooth pipes are placed in parallel columns for purposes of comparison. It will be seen that beginning with the small pipes D'Arcy's coëfficients have, for the same diameter, a greater value than Kutter's, but that as the diameters increase, the value of the coëfficients approach nearer to each other, until at 14 inches diameter they are equal. From this point as the diameters increase, Kutter's coëfficients are the greater, the difference increasing with the increased diameter of pipes. For diameters greater than 10 feet D'Arcy's coëfficient is almost constant. It increases very little more than 113.5 even for a diameter of 16 feet or more, but Kutter's coëfficient continues to increase until such a diameter is reached as is never likely to be required in practice.

Now, the experiments on which D'Arcy's formula is based were made on clean pipes, of the diameters usually adopted in practice, flowing under pressure and under conditions somewhat similar to pipes in actual use, and therefore, as the experiments were conducted with great accuracy, the results are entitled to the confidence of engineers. D'Arcy's experiments did not, however, include pipes of a very large hydraulic mean radius.

Kutter's formula is derived not only from experiments made on channels with small hydraulic radius, but also on channels

with large hydraulic radius, and his coëfficients for very large pipes are therefore more likely to agree with the actual discharge than D'Arcy's constant coëfficent of 113.5 for very large pipes. But again Kutter's formula is open to the objection that it is based on experiments made on open channels. I may here remark, although it is only remotely connected with pipe discharge, that Major Allan Cunningham states, as the result of his extensive experiments for four years on the Ganges Canal, that Kutter's formula alone, of all those tried by him, was found generally applicable to all conditions of discharge, and that it gave nearer results to the actual velocity than any of the other formulæ tried by him. It gave results with a difference from the actual velocity seldom exceeding $7\frac{1}{2}$ per cent., and usually much less than that. When we contrast the wide divergence of the old formulæ under varying flow from the actual velocity, with the results obtained by Kutter's formula, it will be seen that the latter is the most accurate formula for channels with large hydraulic mean radius.

In tables 2 and 3 the values of the factors of Kutter's formula are not given for diameters less than 5 inches. Mr. L. D'A. Jackson, C. E., in his *Hydraulic Manual*, states:

"For the present and until further experiments have thrown "more light on the subject, it may be assumed that the co-"efficient of discharge for all full cylindrical pipes, having a "diameter less than 0.4 feet, will be the same as those of that "diameter."

Although Mr. Jackson's opinion is entitled to great weight, still the facts all tend to prove that the coëfficents of diameters below 5 inches should diminish with the diminution of diameter. The smaller the diameter the more effect will the roughness of the surface have in diminishing the discharge. Table 5 shows that Kutter's coëfficient for 5 inches diameter with $n = .011$ is 82.9 and therefore, according to Mr. Jackson, all the diameters from 5 inches to $\frac{3}{8}$ inch should have a co-efficient of 82.9. This is contrary to the principle of Kutter's formula, the accuracy of which is due to the fact that, other things being equal, its coëfficient vary with the diameter. The following proofs are given

in support of the opinion that coëfficients of diameters below 5 inches should diminish according to the diminution of diameter.

1. In Table 6 the coëfficients of D'Arcy's formula are seen to diminish. At 5 inches diameter the coëfficient is 103.8 and at $\frac{3}{8}$ inch diameter 59.4.

2. In table 6 the coëfficient of Fanning's formula diminish from 4 inches diameter with a coëfficient of 103.4 to one inch diameter with a coëfficient of 80.4.

These coëfficients are derived from the mean velocities in clean pipes with a slope of 1 in 125 given in Fanning's tables.

3. In table 6 the coëfficients, as found by Kutter's formula with a slope of 1 in 1,000, and $n = .011$, are for 5 inches diameter 82.9, and for $\frac{3}{8}$ inch diameter 32.0.

The facts therefore show that the coëfficients diminish from a diameter of 5 inches to smaller diameters, and it is a safer plan to adopt coëfficients varying with the diameter than a constant coëfficient. No opinion is advanced as to what coëfficients should be used with Kutter's formula for small diameters. The facts are simply stated, giving the results of well known authors.

As the coëfficients of D'Arcy's formula vary only with the diameter, the values of the factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ given in table 1 for D'Arcy's formula are practically the exact values for all diameters and slopes given, and the results found by the use of the tables will be the same as the results found by using the formula.

Kutter's factors as given in the tables, are, however, absolutely exact for only one slope, that of 1 in 1,000; but for the slopes given in actual practice to pipes, sewers, conduits, etc., the use of the factors gives results differing so little from the results derived from the use of the complicated formula (6) that the values of the factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ given in the tables may for all practical purposes be accepted as sufficiently accurate.

In tables 2 and 3 the values of $c\sqrt{r}$ and $a\,c\sqrt{r}$ for Kutter's formula differ by a small quantity from the actual values as found by the use of formula (6). These values by Kutter's formula depend not only on r, but also on n and s, so that a

change in any of these three quantities causes a change in the values of $c\sqrt{r}$ and $a\,c\sqrt{r}$. It is found, however, that the slope of 1 in 1,000 will give coëfficients which practically differ very little from the coëfficients derived from the slopes usually given to lines of pipe.

The values of the coëfficients from Kutter's formula given in the tables have been computed for a slope of 1 in 1,000, and they give values of $c\sqrt{r}$ and $a\,c\sqrt{r}$ near enough for practical work.

The two tables 7 and 8 show how small is the difference between the velocity found by the tables of factors and the velocity found by formula (6). The difference seldom reaches more than three per cent., and it is generally less than one per cent. In most cases this degree of accuracy will be deemed sufficient, but should the engineer prefer to use formula (6), even then the tables of factors will give a ready means of checking the computations.

Explanation and Use of the Tables.

The velocity mentioned below means mean velocity in feet per second. The discharge mentioned below means the discharge in cubic feet per second.

1. What is the velocity and discharge by Kutter's formula of an iron pipe of 2 feet diameter and with a fall of 9 feet per mile the value of n being assumed equal to .013.

By formula (9) $\quad V = c\sqrt{r} \times \sqrt{s}$

and by formula (13) $\quad Q = a\,c\sqrt{r} \times \sqrt{s}$

In table 4 look out the value of $\sqrt{s}$ corresponding to a fall of 9 feet per mile, and it is found $=$ .041286. Look out also in table 3 the value of $c\sqrt{r}$ and $a\,c\sqrt{r}$ opposite a diameter of 2 feet, and they will be found to be respectively equal to 71.49 and 224.63—substituting the values so found in equations (9) and (13), and we have—

$V = 71.49 \times .041286 = 2.95$ feet per second velocity.

$Q = 224.63 \times .041286 = 9.27$ c. ft. per second discharge.

If the velocity and discharge are found by Kutter's formula (6) it will be seen that a very great saving of work is effected by the use of the tables.

2. An iron pipe one foot six inches in diameter, whose natural coëfficient of roughness is assumed = .011, is to have a velocity not to exceed 3 feet per second. What should its slope be by the use of Kutter's formula ?

By formula (11)

$$\sqrt{s} = \frac{V}{c\sqrt{r}}$$

Find by inspection in table 2 the value of $c\sqrt{r}$ opposite 1 foot 6 inches. It is equal to 71.08. Substitute this value and also the given velocity in equation (11) and we have—

$$\sqrt{s} = \frac{3}{71.08} = .042206$$

Look out the nearest value of $\sqrt{s}$ to this in table 4, and it will be found to be .043419 opposite a slope of 10 feet per mile, which is the slope required.

3. A 3 feet 6 inch old iron pipe whose natural coëfficient is assumed = .013 is to be replaced by a new pipe capable of discharging double that of the old pipe, the slope remaining unchanged. What is the diameter by Kutter's formula of the new pipe its natural coëfficient being assumed = .011.

Find by inspection in table 3 the value of $a\ c\sqrt{r}$ opposite 3 feet 6 inches diameter. It is found equal to 1021.1 Then $1021.1 \times 2 = 2042.2$. As the value of n for the new pipe = .011, look out in table 2 the value of $a\ c\sqrt{r}$ nearest to 2042.2 and it is found to be 2072.7 opposite a diameter of 4 feet 3 inches, which is the diameter required.

Look up the values of $c\sqrt{r}$ for each pipe and it will be seen that the velocity in the new pipe is to that in the old as 146 : 106.

4. This example is taken from Weisbach's Mechanics of Engineering.

A system of pipes consisting of one main and two branches is required to discharge by one branch 15 and by another 24 cubic

feet of water per minute. The levels show the main pipe to have a fall of 4 feet in 1,000, the first branch 3 feet in 600, and the other branch 1 foot in 200. What diameter should the pipes have?

For the solution of this example table 1, derived from D'Arcy's formula, will be used.

The main is to discharge 39 cubic feet per minute, equal to 0.65 cubic feet per second with a slope of 1 in 250. One branch 15 cubic feet per minute equal to 0.25 cubic feet per second with a fall of 1 in 200, and the other branch 24 cubic feet per minute = 0.4 cubic feet per second with a fall of 1 in 200.

By inspection find in table 4 the value of $\sqrt{s}$ nearest to 1 in 250 (21 feet per mile) and it is found to be = .063066, and also find the value of $\sqrt{s}$ nearest to 1 in 200 (26 feet per mile). It is found = .070173. By formula (15)

$$a\,c\sqrt{r} = \frac{Q}{\sqrt{s}}$$

$$\therefore \text{ for main pipe } a\,c\sqrt{r} = \frac{0.65}{.063066} = 10.307$$

the nearest value of $a\,c\sqrt{r}$ to this in table 1 is 10.852, opposite which is the diameter 7 inches.

In the same manner for the first branch—

$$a\,c\sqrt{r} = \frac{0.25}{.070173} = 3.562$$

and the nearest value of $a\,c\sqrt{r}$ to this, in table 1, is 4.561 corresponding to a diameter of 5 inches.

For the second branch—

$$a\,c\sqrt{r} = \frac{0.4}{.070173} = 5.7$$

and the nearest value of $a\,c\sqrt{r}$ to this, in table 1, is 7.3 opposite a diameter of 6 inches. The required diameters are therefore: for the main pipe 7 inches, for the first branch 5 inches, and for the second branch 6 inches.

Although the explanation of this example, in the use of the tables may appear somewhat long, still the actual work can be done very rapidly and with little trouble. If a comparison is made of the work required for the solution of this example, as given above by the tables, with the work required for its solution by the method of approximations as given in Weisbach's Mechanics of Engineering, from which the example is extracted, it will be seen that there is a great saving of labor effected by the use of the tables.

A more extensive table of slopes and $\sqrt{s}$ than table 4, and also table of factors for circular and egg-shaped brick sewers with $n = .015$ are given in "Hydraulic Tables" in No. 67 of Van Nostrand's Science Series by the writer of this paper.

TABLE 1.—Circular Pipes, Conduits, etc., flowing under pressure. D'Arcy's formula for clean pipes.

Table giving the values of a and r, and also the values of the factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ for use in the formulæ

$$V = c\sqrt{r} \times \sqrt{s} \qquad Q = a\,c\sqrt{r} \times \sqrt{s}$$

These factors are to be used only for clean pipes under pressure.

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
0	$\frac{3}{8}$	.00077	.0078	5.251	.00403
0	$\frac{1}{2}$	.00136	.0104	6.702	.00914
0	$\frac{3}{4}$	.00307	.0156	9.309	.02855
0	1	.00545	.0208	11.61	.06334
0	$1\frac{1}{4}$	.00852	.0260	13.68	.11659
0	$1\frac{1}{2}$	.01227	.0312	15.58	.19115
0	$1\frac{3}{4}$	.01670	.0364	17.32	.28936
0	2	.02186	.0417	18.96	.41357
0	$2\frac{1}{2}$	0.0341	0.052	21.94	.74786
0	3	0.0491	0.063	24.63	1.2089
0	4	0.0873	0.084	29.37	2.5630
0	5	0.136	0.104	33.54	4.5610
0	6	0.196	0.125	37.28	7.3068
0	7	0.267	0.146	40.65	10.852
0	8	0.349	0.167	43.75	15.270
0	9	0.442	0.187	46.73	20.652
0	10	0.545	0.208	49.45	26.952
0	11	0.660	0.229	52.16	34.428
1	0	0.785	0.250	54.65	42.918
1	2	1.069	0.292	59.34	63.435
1	4	1.396	0 333	63.67	88.886
1	6	1.767	0.375	67.75	119.72
1	8	2.182	0.417	71.71	156.46
1	10	2.640	0.458	75.32	198.83
2	0	3.142	0.500	78.80	247.57
2	3	3.976	0.562	83.77	333.08
2	6	4.909	0,625	88 39	433.92
2	9	5.939	0.687	92.90	551.72
3	0	7.068	0.750	97.17	686.76

TABLE 1.—*Continued.*

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
3	3	8.295	0.812	101.2	839.38
3	6	9.621	0.875	105.1	1011.2
3	9	11.044	0.937	108.9	1202.7
4	0	12.566	1.000	112.6	1414.7
4	3	14.186	1.062	116.1	1647.6
4	6	15.904	1.125	119.6	1901.9
5	0	19.635	1.250	126.1	2476.4
5	6	23.758	1.375	132.4	3146.3
6	0	28.274	1.500	138.4	3912.8
6	6	33.183	1.625	144.1	4782.1
7	0	38.485	1.750	149.6	5757.5
8	0	50.266	2.000	160.0	8043.0
9	0	63.617	2.250	169.8	10804.
10	0	78.540	2.500	179.1	14066.

TABLE 2.—Circular Pipes, Conduits, etc., flowing full. Kutter's formula with $n = .011$.

Table giving the values of a and r and also the values of the factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ for use in the formulæ.

$$V = c\sqrt{r} \times \sqrt{s} \qquad Q = a\,c\sqrt{r} \times \sqrt{s}$$

These factors are to be used only where the value of n, that is the coëfficient of roughness of lining of channel, = .011, as for surfaces carefully plastered with cement with one-third sand in good condition, also for iron, cement and terra cotta pipes, well jointed and in best order, and also surfaces of other material equally rough.

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
0	5	0.136	0.104	26.76	3.6398
0	6	0.196	0.125	30.93	6.0627
0	7	0.267	0.146	34.94	9.3294
0	8	0.349	0.167	38.77	13.531
0	9	0.442	0.187	42.40	18.742
0	10	0.545	0.208	45.85	24.976
0	11	0.660	0.229	49.46	32.644
1	0	0.785	0.250	52.85	41.487
1	2	1.069	0.292	59.13	63.210
1	4	1.396	0.333	65.21	91.037
1	6	1.767	0.375	71.08	125.60
1	8	2 182	0.417	76.76	167.50
1	10	2.640	0.458	82.11	216.76
2	0	3.142	0.500	87.36	274.50
2	3	3.976	0.562	94.84	377.07
2	6	4.909	0.625	102.0	500.78
2	9	5.939	0.687	109.0	647.18
3	0	7.068	0.750	115.7	817.50
3	3	8.295	0 812	122.1	1013.1
3	6	9.621	0.875	128.3	1234.4
3	9	11.044	0.937	134.4	1484.2
4	0	12.566	1.000	140.4	1764.3
4	3	14.186	1.062	146.1	2072.7

TABLE 2.—*Continued.*

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
4	6	15.904	1.125	151.7	2413 3
5	0	19.635	1.250	162.6	3191.8
5	6	23.758	1.375	173.1	4111.9
6	0	28.274	1.500	183.1	5176.3
6	6	33.183	1.625	192.7	6394.9
7	0	38.485	1.750	202 0	7774.3
8	0	50.266	2.000	219.7	11044.
9	0	63.617	2.250	236.6	15049.
10	0	78.540	2.500	252.5	19834.

TABLE 3.—Circular Pipes, Conduits, etc., flowing full. Kutter's formula with $n = .013$.

Table giving the values of a and r, and also the values of factors $c\sqrt{r}$ and $a\,c\sqrt{r}$ for use in the formulæ.

$$V = c\sqrt{r} \times \sqrt{s} \qquad Q = a\,c\sqrt{r} \times \sqrt{s}$$

These factors are to be used only where the value of n, that is the coëfficient of roughness of lining of channel = .013 as in ashlar and well laid brickwork, ordinary metal, earthenware and stoneware pipe, but not new, cement and terra cotta pipe not well jointed nor in perfect order, plaster and planed wood in imperfect or inferior condition, and also surfaces of other material equally rough

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
0	5	0.136	0.104	21.20	2.8839
0	6	0.196	0.125	24.60	4.8216
0	7	0.267	0.146	27.87	7.4425
0	8	0.349	0.167	31.00	10.822
0	9	0.442	0.187	34.00	15.029
0	10	0.545	0.208	36.87	20.095
0	11	0.660	0.229	39.84	26.296
1	0	0.785	0.250	42.65	33.497
1	2	1.069	0.292	47.85	51.157
1	4	1.396	0 333	52.90	73.855
1	6	1.767	0 375	57.80	102.14
1	8	2.182	0.417	62.58	136.54
1	10	2.640	0.458	67.07	177.07
2	0	3.142	0.500	71.49	224.63
2	3	3.976	0.562	77 77	309.23
2	6	4.909	0.625	83.82	411.27
2	9	5.939	0.687	89.71	532.76
3	0	7.068	0.750	95.37	674 09
3	3	8.295	0.812	100.9	836.69
3	6	9.621	0.875	106.1	1021.1
3	9	11.044	0.937	111.3	1229.7
4	0	12.566	1.000	116.5	1463.9
4	3	14.186	1.062	121.4	1722.0

TABLE 3.—*Continued.*

d = diameter in feet.	ins.	a = area in square feet.	r = hydraulic mean depth in feet.	For velocity $c\sqrt{r}$.	For discharge $a\,c\sqrt{r}$.
4	6	15.904	1.125	126.2	2007.0
5	0	19.635	1.250	135.4	2659.0
5	6	23 758	1.375	144.3	3429.2
6	0	28.274	1.500	152.9	4322.9
6	6	33.183	1.625	161.2	5339.7
7	0	38.485	1.750	169.2	6510.6
8	0	50.266	2.000	184.5	9272.6
9	0	63.617	2.250	199.1	12663.0
10	0	78.540	2.500	212.8	16709.0

TABLE 4.—Giving fall in feet per mile; the distance corresponding to a fall of one foot and also the values of s and $\sqrt{s}$.

$s = \frac{h}{l}$ = sine of slope = fall of water surface (h) in any distance (l) divided by that distance.

Fall in feet per mile.	Slope one in	s	$\sqrt{s}$.
1	5280	.000189393	.013762
2	2640	.000378787	.019463
3	1760	.000568182	.023836
4	1320	.000757576	.027524
5	1056	.000946969	.030773
6	880.0	.001136364	.033710
7	754.3	.001325797	.036411
8	660.0	.001515151	.038925
9	586.6	.001704545	.041286
10	528.0	.001893939	.043519
11	443.6	.002083333	.045643
12	440.0	.002272727	.047673
13	406.1	.002462121	.049620
14	377.1	.002651515	.051493
15	352.0	.002840909	.053300
16	330.0	.003030303	.055048
17	310.6	.003219696	.056742
18	293.3	.003409090	.058388
19	277.9	.003598484	.059988
20	264.0	.003787878	.061546
21	251.4	.003977272	.063066
22	240.0	.004166667	.064549
23	229.6	.004356060	.066000
24	220.0	.004545454	.067419
25	211.2	.004734848	.068810
26	203.1	.004924242	.070173
27	195.2	.005113636	.071510
28	188.6	.005303030	.072822
29	182.1	.005492424	.074111
30	176.0	.005681818	.075378
31	170.3	.005871219	.076624
32	165.0	.006060606	.077850

TABLE 4, *(Continued.)*

Fall in feet per mile.	Slope one in	s	$\sqrt{s}$.
33	160.0	.006250000	.079057
34	155.3	.006439393	.080246
35	150.9	.006628788	.081417
36	146.6	.006818181	.082572
37	142.7	.007007575	.083711
38	139.0	.007196969	.084835
39	135.4	.007386363	.085944
40	132.0	.007575757	.087039
41	128.8	.007765151	.088120
42	125.7	.007954545	.089188
43	122.8	.008143939	.090244
44	120.0	.008333333	.091287
45	117.3	.008522727	.092319
46	114.8	.008712121	.093339
47	112.3	.008901515	.094348
48	110.0	.009090909	.095346
49	107.7	.009280303	.096334
50	105.6	.009469696	.097312
51	103.5	.009659090	.098281
52	101.5	.009848484	.099241
53	99 60	.010037871	.100189
54	97.77	.010227273	.101130
55	96.00	.010416667	.102060
56	94.28	.010606060	.102983
57	92.63	.010795454	.103901
58	91.03	.010984848	.104809
59	89.49	.011174242	.105708
60	88.00	.011363636	.106600
65	81.23	.012310606	.110953
70	75.43	.013257575	.115141
80	66.00	.015151515	.123091
90	58.66	.017045454	.130559

TABLE 4, *(Continued.)*

Fall in feet per mile.	Slope one in	s	$\sqrt{s}$.
100	52.80	.018939393	.137620
120	44.00	.022727272	.150756
140	37.71	.026515151	.162835
160	33.00	.030303030	.174077
180	29.33	.034090909	.184637
200	26.40	.037878787	.194625
240	22.00	.041666667	.213200
280	18.86	.053030303	.230283
320	16.50	.060606060	.246183
360	14.66	.068181818	.261116
400	13.20	.075757575	.275241
450	11.73	.085227272	.291937
500	10.56	.094696969	.307729
600	8.800	.113636363	.337100
700	7.543	.132575757	.364109
800	6.660	.151515151	.389249
900	5.866	.170454545	.412861
1000	5.280	.189393939	.435194
1500	3.520	.284090909	.532925

TABLE 5.—Comparison of coëfficients (c) in the formula.

$$V = c\sqrt{rs}.$$

D'Arcy's coëfficients for clean pipes under pressure.—Kutter's coëfficients for pipes flowing full with $n = .011$ and $s = .001$.

Diameter. Ft. Ins.	D'Arcy's Coëfficients for clean pipes.	Kutter's Coëfficient, $n = .011$ $s = .001$	Diameter. Ft. Ins.	D'Arcy's Coëfficient for clean pipes.	Kutter's Coëfficient, $n = .011$ $s = .001$
0 5	103.8	82.9	2 9	112.1	131.5
0 6	105.3	87.4	3 0	112.2	133.6
0 7	106.4	91.5	3 3	112.3	135.6
0 8	107.2	95.0	3 6	112.4	137.2
0 9	107.9	97.9	3 9	112.5	138.8
0 10	108.5	100.5	4 0	112.6	140.4
0 11	108.9	103.3	4 3	112.7	141.7
1 0	109.3	105.7	4 6	112.7	143.0
1 2	109.9	109.5	5 0	112.8	145.4
1 4	110.4	113.0	5 6	112.9	147.6
1 6	110.7	116.2	6 0	113.0	149.5
1 8	111.0	118.8	6 6	113.0	151.2
1 10	111.3	121.3	7 0	113.1	152.7
2 0	111.5	123.6	8 0	113.2	155.4
2 3	111.7	126.5	9 0	113.2	157.7
2 6	111.9	129.1	10 0	113.3	159.7

TABLE 6.—Of coëfficients (c) from the formulæ of D'Arcy, Kutter and Fanning for small pipes below 5 inches in diameter.

$$V = c\sqrt{rs}.$$

Diameter in Inches.	(c) D'Arcy's Coëfficient for clean pipes.	(c) Kutter's Coëfficient from formula $n = .011$ $s = .001$	(c) Kutter's Coëfficient recommended by L.D.A.Jackson.	(c) Fanning's Coëfficient for clean iron pipes.
0 $\frac{3}{8}$	59.4	32.0	82.9	
$\frac{1}{2}$	65.7	36.1	82.9	
$\frac{3}{4}$	74.5	42.6	82.9	
1	80.4	47.4	82.9	80.4
$1\frac{1}{4}$	84.8	51.9	82.9	
$1\frac{1}{2}$	88.1	55.4	82.9	88.0
$1\frac{3}{4}$	90.7	58.8	82.9	92.5
2	92.9	61.5	82.9	94.8
$2\frac{1}{2}$	96.1	66.0	82.9	
3	98.5	70.1	82.9	96.6
4	101.7	77.4	82.9	103.4
5	103.8	82.9	82.9	

TABLE 7.—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of n being .011.

Diameter, Feet.	Inches.	Slope one in	Velocity. by Kutter's formula.	Velocity. by Flynn's tables.
1	0	66	6.62	6.51
1	0	2640	1.02	1.03
2	0	66	10.89	10.75
2	0	2640	1.67	1.70
4	0	66	17.52	17.28
4	0	2640	2.70	2.73
6	0	66	22.63	22.54
6	0	2640	3.54	3.56

TABLE 8.—Showing the velocity in feet per second in pipes, by Kutter's formula (6) and also by the tables, the value of n being .013.

Diameter, Feet.	Inches.	Slope one in	Velocity. by Kutter's formula.	Velocity. by Flynn's tables.
1	0	66	5.34	5.25
1	0	2640	0.81	0.83
2	0	66	8.91	8.80
2	0	2640	1.36	1.39
4	0	66	14.44	14.34
4	0	2640	2.24	2.27
6	0	66	18.91	18.82
6	0	2640	2.94	2.98

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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XVI.

(VOLUME II —FEBRUARY, 1885.)

ON THE RECENT PROGRESS IN ELECTRICITY.

By E. J. MOLERA, Mem. Tech. Soc.

Read February 6, 1885.

The branch of Physics which treats of Electricity has had, in the last few years, a phenomenal development. The scant knowledge of this subject which was imparted to the student in technical education of the past, embraced the main part of what was then known in that department of Science; to-day, so great has been the amount of information accumulated on the subject of Electricity, and so extended the investigations, that special colleges for the training of Electrical Engineers or Electricians, have been established in many parts of Europe.

In the great World's Exhibitions, the department of Electricity was a few years ago represented by a few scientific instruments and telegraphic apparatus. At the present time, the electrical department at international expositions ranks among the most extensive and important of all exhibits. The ever-increasing applications of electricity to the Arts now require special exhibitions. In 1881, the Paris Electric International Exhibition was inaugurated as an experiment. It has been followed by the Munich, Vienna and Philadelphia International Electric Exhibitions, together with many others of a national character.

The literature on electrical subjects has increased at a greater rate than that of any other branch of science; not less than six illustrated periodicals on electricity being published in this country alone.

Societies of electricians have been instituted both at home and abroad, to which, like the Paris International Society of Electricians, belong some of the most noted men of science in the world.

By means of international conferences and conventions, new theories have been advanced, complex questions elucidated, and systems of measurements and nomenclature adapted with such unity of purpose, that the (C. G. S.) system, promulgated by the Paris Congress a few years ago, is now exclusively used by all electricians.

Not only in the domain of science and research has electricity advanced with great strides, but even in the industrial applications, electricity has permeated all the technical professions. The military engineer avails himself of this most ready agent of nature for the explosions of mines both on land and in water, and for the detection of the enemy at night. The civil engineer uses it for blasting and quarrying, for signals in geodetic surveys, and for many other purposes. The mining engineer finds it useful for the underground illumination of his workings, for the transportation of material and rapid communication, while his brother co-worker, the metallurgist, employs it for the electro-deposition of metals.

Chemistry and electricity are to a certain extent so entwined with one another that a thorough chemist must be more or less an electrician and vice versa.

The scientist, the astronomer and meteorologist could not carry on their minute and accurate measurements without having recourse to electricity. Instruments for electrical testing and measurement have been so improved, and their use so extended, that measurements which were rare and difficult in the best appointed laboratories a few years ago, are now made by students, and even workmen at the electric construction and lighting company's works.

In the realm of pure science, electricity by the marvelous swift-

ness of its effects, facility of production, and its capability of subdivision both in intensity and quantity, has rendered invaluable services to the investigator and philosopher; and in the hands of Thompson, Crooks, Clark Maxwell, Hughes and others, has given us a better insight into the composition of bodies and the phenomena of Nature.

Financially considered the industrial applications of electricity have attained great success

Half a century ago the first telegraphic wire was stretched by Gaus and Weber at Göttingen, Germany. Soon after, Wheatstone in England and Morse in this country constructed their first telegraphic lines. Even after the first trials, conducted by Morse in this country, proved beyond cavil the practicability of the electric telegraph, capitalists were very slow to invest their money in such enterprises. The first line between New York and Washington through Philadelphia and Baltimore was built by Cornell in 1845, with great difficulty. In 1855, that line was consolidated with two other western lines, which resulted in the organization now known as the Western Union Telegraph Co., one of the most powerful and important corporations in the world. This company owns 500,000 miles of telegraphic wire; 12,500 telegraph offices, and employ 20,000 persons. The gross earnings for the last year were $19,500,000, and the net profits nearly $8,000,000.

The trans-Atlantic cables cost upwards of $72,000,000, and earn sufficient money to pay a large interest on the capital invested.

The Telephone has a still more rapid growth. Few of the visitors at the Centennial Exhibition will doubtless remember the pair of telephones there exhibited by Prof Bell. For those who saw them, they hardly provoked any more curiosity than the so-called "lover's telephone." It only rose to the consideration of the public, by the expression of admiration and surprise published by a man of genius, Sir William Thompson. At the recent Philadelphia International Electric Exhibition, the original telephone switch board was exhibited. It has six switches, with the names of the first six subscribers, and room enough for another six subscribers, with the hope that in future the number

of patrons might reach a dozen! To-day Boston has over 2,400 subscribers. The Bell Co. has a capital of $8,000,000 and net earnings of nearly $2,000,000.

Having been for the last year the representative of the electrical section of this Society, it appears to me to be appropriate to give here a brief resumé of the recent progress in Electricity.

Batteries.—The most novel batteries brought out during the last year, are the Sun batteries and Laland's. The Sun batteries convert directly the radiant energy of light into electric energy. Two different batteries of this class have been made, one by Herr Sauer, and the other by C. E. Fritts. The first is composed of two electrodes; one of platinum, and the other of sulphide of silver. The former is immersed in a solution of common salt, and the latter in mercury. The Fritts battery is made of selenium cells. The cells are composed of very thin plates of selenium, which are melted on a metallic plate. This thin sheet of selinum is in turn covered with gold leaf. When these batteries are exposed to sunlight, an electric current is originated without chemical action.

The Laland's cell is composed of an iron tray, in which is placed a layer of oxide of copper. On top of it, but without touching the oxide of copper, a zinc plate is placed; the tray is then partially filled with a solution of caustic soda. The soda decomposes the zinc only when the circuit is closed; when the oxygen of the oxide of copper combines with the zinc, it produces oxide of zinc, leaving metallic copper as a residuum. It is stated that the oxide of zinc is 25 per cent. more valuable than the zinc, and that the copper can be regained at a trifling expense. This battery is indorsed by Spence & Co., manufacturing chemists, and has been in use for some time in London.

Electric Telegraph and Telephones.—The vital question in the electric conveyance of intelligence is the changing of the ærial lines for those underground. There are at present so many wires stretched along the streets of large cities, for telegraphic and telephonic purposes that a crusade against ærial lines has been inaugurated. It has succeeded to the extent of causing the legislature of the State of New York and the City of Philadelphia

to enact laws for their abolishment, and the substitution of underground lines. These laws, if not repealed are intended to abolish all ærial lines in those cities before the end of the present year.

But it is easier to pass laws than to change or even direct those of Nature, so that though many electricians have undertaken to solve the problem of underground electric lines, none has as yet succeeded. The first electric lines were built under ground, but they failed on account of the poor insulation of the wires. This difficulty has been overcome since the use of gutapercha, but has not remedied the static and dynamic induction to which causes are due the confusing noises and running of words together which are noticed on telephonic lines and retardation in telegraphic ones. Underground lines cost four times as much as ærial lines, and only one-quarter the amount of work can be accomplished with them when compared to ærial lines.

The most remarkable inventions in telegraphy during the past year are Selden's Sextuplex and Delaney's Synchronous Multiplex systems.

By Selden's system three messages can be sent simultaneously from each end of the line, or six in all. According to tests made by the Baltimore and Ohio Telegraph Co., the system works well, and it is the intention of that company to adopt it.

By means of Delaney's system, as many as 72 messages can be transmitted on one wire at once, any fraction of 72 in one direction and the balance in the other. A great advance over any other system.

To give an idea of this system, imagine a certain number of telegraphic lines placed parallel to one another, and in which the line wire has been removed. Then take one of the wires and connect it successively to each pair of instruments. The lines will be completed one after the other in succession, and they can then be operated. It is evident that this object can also be attained by having the one wire stationary and bringing to it each pair of instruments. If the instruments can be connected more rapidly than the fastest movements of the telegraphic instruments, say 20 or 30 a second, then the circuits would be practically continuous, though in reality a rapid succession of

electrical impulses would be sent to each pair of instruments; if the same pair of instruments were connected simultaneously, then telegraphic messages could be sent independently from each pair of instruments.

In Delaney's system this has been obtained by connecting both ends of the line with a revolving arm, which by proper mechanism connects the different telegraphic apparatus. The essential principle of the system is the perfect synchronism of the two arms which is produced by two forks of the same tune, the vibrations of which are regulated by a contrivance which sends automatically electric impulses to the apparatus whose tuning fork falls in its rate of vibration. It is asserted that by such means the two arms will revolve for weeks at a time without their positions differing $\frac{1}{100}$ of an inch or the $\frac{1}{1000}$ of a second.

This system has been lately introduced in a line from Boston to Providence.

Another novelty in telegraphy tried very recently is the Phelps induction telegraph system, which consists of an insulated wire laid on the track of a railroad line, the wire being connected with proper instruments. A copper wire coil is placed under the car of a train at a distance of six or eight inches from the line wire; the ends of the coils-wire are connected with a telegraphic instrument inside the car. Whenever a message is sent from the instruments in the car, by induction on the line wire, it is transmitted to the receivers along the line, and vice versa, when a message is sent from the instruments in the line, the same is transmitted by induction to the receiving instruments in the car. This system was tried not long ago on the Harlem River Railroad, and any number of messages were sent from the trains to the several stations, but it was not so successful in receiving messages from the line to the train.

This year inaugurates the Commercial Trans-Atlantic Cable, owned by our bonanza king, Mr. Mackey, and Mr. Bennett, of the N. Y. Herald. In this cable the new improvements known as Muirhead's duplex system and Sir Wm. Thompson's syphon recorder, have been introduced. With this cable the rates have been reduced to 40 cents per word as against $4.60 that was charged by the first trans-Atlantic cable company.

Telephone.—Dolbear's Electro-Static Telephone was exhibited for the first time at the last Philadelphia Electric Exhibition. Two telephones at a short distance without being connected with any wire or conductor more than the intervening air, act by the induction of one instrument upon another in such a way that, words spoken before one instrument, can be heard at the other. In Bell's Radiophone a beam of light is the conductor; but in Dolbear's no special conductor is used. Telephones have also been used lately in a novel manner, viz: for the purpose of signaling between two ships at sea. For that purpose two telephonic instruments are placed on board, one on each ship, with their terminals plunging into the water. In that manner signals have been transmitted from one vessel to another at short distance. Should the distance where signals by this method could be transmitted be increased, it would prove very valuable to navigation. The improvement is due to Professor Bell, the well known inventor of many other telephonic devices.

Improvements in the construction of instruments has made possible distance where telegraphic and telephonic signals can be transmitted greater every year. Telegraphic signals have been transmitted recently from London to Calcutta, a distance of 7,000 miles, and telephonic conversation has been carried from New York to Cleveland, and even as far as Chicago, a distance of nearly 1 000 miles.

The introduction, in England, of accumulators instead of the ordinary batteries, and the working of telegraphic and telephonic instruments from the same wire close the list of recent innovations.

Electric Light.—Nothing of a startling character has been produced lately in this department. A large number of incandescent lights of great power have been put up and are now manufactured for a variety of purposes. Their power ranges from a fraction of a candle to 500 candle power. The running of arc and incandescent lights from the same wire was introduced for the first time during the past year by the Negus system.

The electric light is now used on nearly every large steamer and man-of-war. It has also been employed on several railroad lines, both for car illumination as well as for the locomotive head

lights. The incandescent lights are used for the former, and the arc lights for the latter purpose. They are actuated by dynamos run either by a separate steam engine or by the car axles. When run by the car axles accumulators are required.

Electric Locomotion.—Electricity was first applied in a practical way for the purpose of locomotion by Siemens of Berlin in 1879. In 1881 a longer line was constructed in that city by the same firm. This line was followed by one inaugurated in the same year, at the Giant Causeway, England. At the Vienna and Paris Exhibitions there were electric railroad lines which were constructed and operated by Siemens.

Electric railroad lines were introduced in America for the first time last year. One, built by Knight and Bentley, was inaugurated at Cleveland. Two other lines have been built latterly in connection with the Philadelphia and Boston Electric Exhibitions. The Daft Co. are now engaged in changing the cable system of propulsion at the Brooklyn Bridge to their electric motor. A railroad run with an electro-motor has been constructed at Toronto, Canada.

The several lines are operated with dynamos, actuated by electricity, which is conveyed through the rails or special conductors placed between them by means of a stationary dynamo. By another method (originally invented by the writer) cars are run with dynamos actuated by accumulators carried on the same car or on separate dummies. This system has been tried with promising results in Europe by the Electric Power Co., and in this city by the writer. Durable accumulators for permanent work have not as yet been constructed, though they are being daily improved. It is not improbable that in time accumulators will be used for the propulsion of cars and likewise for omnibuses and carriages. Recent experiments conducted by the Electric Power Co. of London, in operating street car lines by means of dynamos and accumulators, are reported to have been very successful. Launches have been propelled successfully by accumulators, though the cost is stated to be 2.5 times as great as steam; but considering that no smoke, cinders, heat or smell is derived from their use, if expense is not of vital importance they may be employed.

With the name of Telpherage aerial lines for the conveyance of small parcels by means of electro-motors has been introduced. The writer had devised, several years ago, similar lines for another purpose.

Captains Renard and Krebs of the French engineer corps have propelled, directed, and controled recently balloons with a degree of success never before obtained. Two expeditions were made last year in balloons from Chalais, near Paris, and a velocity of 12 miles per hour was attained.

Transmission of Power by Electricity.—The most important problem now presented to electricians is the question of the transmission of power at great distances. On its solution depends the use of nearly 500,000 H. P., now derived in the U. S. from hydraulic plans, in out of the way places, availed where the commodities they manufacture are consumed, avoiding the isolation of factory hands and the transportation of goods. It will permit the utilization of the energy of Niagara Falls from which source several million horse powers may be obtained. This power, if properly employed, would be sufficient in many places to run cars, machines for lighting and warming houses, and could be used for cooking purposes.

The power stored in coal measures and petroleum reservoirs, would be obtained in *situ*, and transported where needed.

Several years ago Prof. Thomson of Glasgow announced that with a copper wire one-half inch in diameter, 27,000 H. P. could be transmitted from Niagara Falls to New York, with a loss of only 7,000 H. P. Other authorities give different results.

Marcel Desprez has studied the question from a theoretical and practical stand-point. His object has been to transmit electrical energy by means of the existing types of machines and wires. In 1881 he presented to the French Academy of Sciences a lucid explanation of his theory. One year later facilities were given him at the Munich Electrical Exhibition to test his theory. He succeeded in transmitting one-half H. P., from Misbaden to Munich, a distance of 59 kilometers, through an ordinary telegraphic wire with a loss of 62%. In 1883 he made a new trial at the North Railroad Station in Paris, where 4 H. P. were transmitted a distance of 17 kilometers with a loss

of 52%. Recently another trial has been made by him, and he has succeeded in transmitting 7 H. P. a distance of 14 kilometers with a loss of only 40%. These trials are not by any means decisive. The main difficulty lies in overcoming the resistance of the electric conductor, which is in proportion to the distance and inverse to the square of its section. To overcome it by increasing the diameter of the conductor is not possible on account of the expense. The other way is by generating electricity of a high electromotive force, which is a very easy matter. The objection to this plan is the difficulty of insulation and the danger of such currents. In the opinion of the writer the difficulty is more apparent than real. Insulation can be effected by substituting for the wooden poles better insulating materials, and as far as danger to life is concerned, the existing electric light conductors would, and do kill occasionally, imprudent persons who touch them. This latter danger can in a great measure be lessened by transforming the electricity of high E. M. force into low E. M. force by means of accumulators, induction coils or converting dynamos. There is no doubt that in the near future currents of many thousand volts will be used, and by their means the cheap transmission of energy will be accomplished. Nothing has been done in this country in this department.

Electro Deposition of Metals.—The system of working metallic ores was first introduced in England and afterwards with better success in Germany. The principal works are at Hamburg, Oker and Eisleben. The details of the processes are everywhere guarded with the utmost secrecy. At Sestri Levante, Italy, copper ore is partially melted into ingots and the latter refined by electrolitic action. The saving of fuel in this manner is 85% of what would be required by the ordinary processes. In all electric deposition of metals the H. P. needed is very high, and in consequence it can be only used where hydraulic power is at hand. In this country Mr. Balbach has started this process of working ore at Newark, N. J.

Electro-magnetic action is sometimes used for the working of ore. At the Friedrichegen mine, Germany, this process is used to separate iron ore from zinc blende.

Electricity for Warfare.—Submarine torpedoes have proved the best means of defense against the attacks of aggressive naval powers. Paraguay kept at bay the whole of the Brazilian navy during the war between those two powers. During the Russo-Turkish war torpedoes and submarine mines were a source of continual apprehension, and the great superiority of the French navy over the Prussian was paralyzed by the actual or reputed existence of torpedoes in German waters. The English at Alexandria, after having silenced the forts, landed and in a few hours destroyed the remaining guns and fortifications with dynamite exploded by means of electricity.

Electricity has been employed extensively in this country for war purposes. The station at Willet's Point under Gen. Abbot, of the torpedo corps, is one of the best appointed, and the experiments conducted there has given very valuable results. Torpedoes are directed from ashore with such a degree of precision and celerity, that it would be very hazardous for any fleet to enter a harbor thus protected in time of war. By means of buoys submarine mines are marked, and any attempt to disturb them at day or night would be followed not only by the explosion of the mine but by shots from guns automatically discharged from the shore.

Electricity has been applied in many different ways, and no less than eleven hundred patents have been taken out in this country during the past year. These patents, apart from the departments already mentioned, embrace drills, riveting machines, medicinal instruments, telemetric instruments, heat-regulators, alarm and house appliances, and many others. Among the problems now before electricians there is none more important than the already alluded transmission of power, tele-optics and the direct conversion of the energy stored in sun-heat and coal into electric energy.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II — FEBRUARY, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

February 6, 1885.

The President and Vice President being absent, the meeting was called to order by the Secretary, and Mr. Fr. Gutzkow was elected President *pro tem.*

The following propositions for membership were made:

Chalmers Scott, proposed by Sanford Robinson, Aug. J. Bowie, Jr., and G. H. Mendell.

John Hays Hammond, proposed by Aug. J. Bowie, Jr., Sanford Robinson, and G. H Mendell.

John Richards, proposed by G. W. Dickie, C. G. Yale, R. Forsyth, and L. Wagoner.

E. J. Molera read a paper "On the Recent Progress in Electricity."

P. J. Flynn read a paper "On Hydraulic Tables Based on the Formulæ of D'Arcy and Kutter."

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

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XVII.

VOLUME II.—MARCH, 1885.

WATER METERS.

Comparative Tests of Accuracy, Delivery, Etc.—Distinctive Features of the Worthington, Kennedy, Siemens and Hesse Meters.

By ROSS E. BROWNE, Mem. Tech. Soc.

Read March 6, 1885.

With the purpose of employing a meter for the measurement of water, in connection with some hydraulic experiments conducted at the University of California, the writer instituted a series of tests of a meter invented by Prof. F. G. Hesse. The accuracy, at various rates of delivery, was carefully determined. The results of these experiments, properly tabulated, furnish a correction for the indicated delivery. It is believed that, where the flow is uniform, the possible error in the corrected index reading may be safely placed at $\frac{1}{4}$ per cent.

The meter is of the class known as *velocity* or *inferential* meters, and is so permanent in its sources of error, as to make it peculiarly adapted to the purpose named.

These experiments led to comparative tests of the Worthington meter. Reliable information was also sought concerning other meters in common use. It is thought that sufficient of interest was developed to warrant this paper, particularly as, in

the course of this investigation, it was noted: that no great amount of accurate and systematic information upon this subject is to be found in the available files of our Engineering and Scientific journals; that the several reports consulted, of Engineers and Superintendents of Water Works, while well answering their immediate purpose, do not furnish facts in sufficient detail to guide the independent judgment of one not familiar with the construction of the meters in competition; that very few of the circulars of the American manufacturing companies supply such data as will answer for comprehensive comparison.*

It will be attempted to bring forward, as fairly as may be, the distinctive features of two of the principal forms of Piston meter —the Worthington and the Kennedy,—and three forms of Velocity meter—the Siemens of English manufacture, the Siemens of German manufacture, and the Hesse meter already mentioned.

The Worthington is widely known in the United States. The Kennedy is one of the most perfect of the meters used in England. The two Siemens meters are probably the most extensively employed in Europe. The Hesse meter has been but recently perfected, and not yet introduced. If undue prominence has been given to the last named meter, the interest of the writer in his special investigation must plead as excuse.

It is to be regretted that this list cannot be made more comprehensive by adding an example of the Rotary Piston form, such as the Crown. It will be understood that, in speaking of the piston meter, special reference is only intended to the Worthington and the Kennedy.

These meters will be considered in the main with reference to their adaptability to house use, or use in the sale by volume of water under pressure.

This being the purpose of a meter, it should fulfill the following conditions:

1st, It should register with a suitable degree of accuracy, the quantity of water delivered at every rate of flow, from that of the maximum capacity of the service pipe, to a rate so small as to

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* The circular of the National Meter Co. of New York is exceptionally complete, though there is missing some of the data necessary to warrant the inclusion of their rotary Crown Meter in the list of meters discussed.

discourage theft. The admissible error is variously placed at from 2 to 5 per cent.

2d, This degree of accuracy should be reasonably permanent, i. e., the meter should not be subject to any change, seriously affecting its accuracy, by wear, by slight deposition of sediment, etc. Sudden opening and closing of the house faucets should not induce any considerable error of registry.

3d, The introduction of the meter should not materially affect the delivery of the service pipe, i. e. should cause no serious loss of effective head or pressure.

4th, The price should be small and the necessary repairs inexpensive.

Notwithstanding the demand and the effort made by inventors to meet these desiderata, such marked success has not been attained as to make it a universal custom to sell water by volume.

In the systems of city supply, there result decided advantages from the employment of the meter. Reckless waste is checked and the consumer is not charged for his neighbors' extravagance. A number of comprehensive articles *have been published upon this subject, and a few points only will be reiterated.

It is claimed that nearly one-half of the water consumed in our cities is uselessly wasted. It is doubtful if this lavish consumption is on the whole a sanitary benefit, the waste being in large part the result either of leakage or of willful negligence, and not of a character to effect any proper flushing of closets and sewers. By placing meters near the point where the service pipes enter the premises, and thus making the consumers responsible for such negligence and for defective plumbing, a wiser use of water is effected. In order to prevent the penurious consumer from pursuing an economy, so stringent as to result in certain sanitary evils, it is recommended that a minimum quantity of say 10 or 20 gallons per capita per diem be established, and the consumer charged for this whether he use it or

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*See article in the *Sanitary Engineer* of May 10th, 1883. Also papers read before the American Water Works Association by John C. Kelly, March 14th, 1882, and by Edwin Darling, April, 1884, published respectively in the circulars of the National Meter Co. of New York, and of the Union Water Meter Co. of Worcester, Mass.

not. The water department of Providence, R. I., makes a minimum charge of $10 per year (equivalent to about 100 gallons per diem) for each meter service. Meters were provided, in Providence, for about one-half the total number of services, and a decided economy effected. The daily consumption at present is about 350 gallons per service, or 25 to 50 per capita—less than one-half the average in American cities.

When the water supply of a city, employing few meters, becomes inadequate to meet the demands of the consumers, two propositions may be entertained: the increasing of the capacity of its water works, and the introduction of meters. It is maintained that in most cases the latter proposition is by far the more economical. As the city grows, it will, from time to time, become necessary to increase the supply; but it is thought much cheaper to keep the meters in repair and maintain water works of sufficient capacity, than to maintain water works of double the capacity without meters.

It seems inevitable that the meter system should rapidly grow in favor with improvement of the present forms of meter. In a few cities their use is already extensive. In London* nearly 40 per cent. of the houses supplied by the various water companies are now provided with meters. In New York and Boston, meters have been introduced into from 5 to 10 per cent. of the services. In Providence, R. I., 50 per cent. In San Francisco 20 per cent. In Oakland 3 or 4 per cent.

The Comparison of Meters.—A just and comprehensive comparison of the merits of competing meters will frequently involve an extended investigation. If, for instance, the extent and effect of wear and rusting are difficult to estimate, prolonged trial may become necessary.

Of the more important considerations in such a comparison, the following are enumerated in an order not pretending to indicate relative importance.

Delivery under various effective heads.

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*See *London Engineer* of Aug. 1, 1884. For detailed information concerning the U. S. and Canada see circular of National Meter Co., N. Y.

Greatest advisable rate of delivery.

Accuracy of registration at various rates of delivery.

Sensitiveness.

Necessity and difficulty of special adjustment.

Permanence of initial degree of accuracy and sensitiveness.

Liability to obstruction.

Compactness.

Price, both upon the basis of delivery and of greatest advisable effective head.

Expense of repairs, including the consideration of the life of the meter.

Head lost in the meter.—By head lost is understood the difference of the heads in the inlet and the outlet openings. If H is the actual head at the inlet and h that at the outlet, then the head lost is H-h. The rate of delivery will depend upon this difference of heads, and not upon the actual magnitude of H and h.

In each of the meters described, the law of loss of head is, within a practical limit, roughly the same—the resistance being mainly due to impact and fluid friction, and therefore approximately proportional to the square of the rate of delivery.

This is about the same as the law of loss in a pipe. Hence the loss of head in a meter is fittingly indicated by the length of pipe of given diameter which will cause the same loss. Thus 10 feet of $\frac{1}{2}$ inch pipe, or 30 feet of $\frac{5}{8}$ inch pipe, will occasion the same loss as the Worthington $\frac{5}{8}$ inch or the Hesse $\frac{1}{2}$ inch meter.

Effective Head.—By effective head is understood the actual head necessary to force water through the meter at a given rate. This is equal then to the "head lost" plus the velocity head in the outlet pipe, and will, in the meters mentioned, be very little greater than the "head lost."

Delivery of the Meter.—It is customary to designate the size of a meter by the diameter of service pipe for which the inlet and outlet openings are fitted. This classification furnishes no general measure of delivery. When the rate of delivery is approximately the same function of the head lost, in each, it is admissible to adopt a unit and classify the meters accordingly.

The loss in the delivery of a service pipe occasioned by the

introduction of a Worthington $\frac{5}{8}''$ or a Hesse $\frac{1}{2}''$ meter, is easily calculated.

Suppose for example the $\frac{5}{8}$ inch service pipe to have a length of 100 feet; also 5 elbows each equivalent, in loss of pressure occasioned, to 5 feet of pipe; also one service cock, together with minor obstructions equivalent to 25 feet of pipe. The equivalent length of pipe, of diameter $d = \frac{5}{8}$ inch, is $l_1 = 150$ feet $= 1800$ inches. After introduction of meter $l_2 = (150+30) \times 12 = 2160$ inches. Weisbach's formula gives

$$v = \sqrt{\frac{2\,g\,H}{1 + \lambda \frac{l}{d}}}$$

wherein H will be the effective head in the main, v the velocity in the service pipe, and λ a coëfficient $= .02$ for such velocities as are here involved. If v_1 represents the velocity before, and v_2 after the introduction of the meter

$$\frac{v^2}{v^1} = \sqrt{\frac{d + \lambda\, l_1}{d + \lambda\, l_2}} = \sqrt{\frac{\frac{5}{8} + .02 \times 1800}{\frac{5}{8} + .02 \times 2160}} = 0.914$$

In other words the meter would occasion, in the case given, a loss: in delivery of service pipe, of about 9%; in effective head back of the faucet, of about $1.00 - (0.914)^2 = 16\%$; in the kinetic energy or capacity for work, of about $1.00 - (0.914)^3 = 24\%$.

Greatest Advisable Rate of Delivery.—When a meter is taxed beyond a certain point it will be seriously damaged. A practical limit in rate of delivery is therefore fixed upon, and this should govern the selection. In addition to this limit in rate of delivery, the corresponding effective head should be given. The allowable effective head in the oscillating piston meters is small, in the rotary piston meters considerably greater, in the velocity meters very high. Where a high head is at hand, and the capacity of the service pipe is great, an oscillating piston meter of large size should be used, whereas it is safe to introduce a comparatively small velocity meter.

Sensitiveness.—The rate of delivery necessary to cause motion of the dial hands, or the greatest quantity per minute which

may pass without causing registration, will be taken as an inverse measure of the sensitiveness of the meter.

The head lost and accuracy of a meter, are conveniently illustrated by means of curves.

Curves of head lost (see diagram).—These were obtained by plotting, on suitable scales, in a rectangular co-ordinate system, the rates of delivery as abscissæ, and the corresponding heads lost, as ordinates.

Curves of Registry (see diagrams).—By recording the measurement of the actual quantity delivered, and the reading of the index, under various rates of flow, the data is obtained for plotting a curve which will illustrate the effect of the change in rate of delivery upon the accuracy of registration. The curves given were obtained by plotting the rates of delivery as abscissæ, and the corresponding per cent. registered of the actual quantity delivered ,as ordinates.

Upon the basis of the considerations enumerated, a comparison of the meters selected has been instituted. A statement of this comparison will be preceded by a detailed description of each meter concerned.

Piston Meters.—In the piston meters mentioned the oscillating pistons displace a quantity of water each stroke. The measure of the quantity delivered, is, in the Worthington the number of strokes, in the Kennedy the approximate distance traveled by the piston. The degree of accuracy for the various rates of delivery, will depend in the Worthington upon the differences in length of stroke, the piston leakage, the action of the valves, &c. In the Kennedy there is a dependency upon, but slight differences in the length of stroke, upon leakage, etc. These and similar meters are frequently termed *volume* or *positive* meters, in contradistinction to *velocity* or *inferential* meters. No assumption of advantage is authorized by such a distinction. The approximate volume is registered in either case, and there is no general difference in the directness of transmission from the measuring part to the index.

Description of the Worthington Piston Meter (see figs. 1, 2, 3, 4_a 4_b) —Letters of reference refer to the same parts in the differ-

ent figures. In this meter two piston plungers are closely fitted in parallel cylinders. By means of two slide valves, the water is admitted under pressure into the chamber at one end of each plunger alternately, while connection is made between the chamber at the other end and the discharge pipe. Thus the piston, in moving, displaces the volume escaping through the discharge pipe. The arrangement is such that the strokes of the two plungers alternate, the valve actuated by the one admitting the pressure to the other. The displacement (area of piston times length of stroke) multiplied by the number of strokes will give approximately the volume of water delivered. The indexing apparatus is arranged to move the dial hands once every fourth stroke, 3 such movements registering $\frac{1}{10}$ cubic foot in the $\frac{5}{8}$-in. meter.

The water enters through opening A into chamber B. In the position of plungers shown, the water then passes through port a (of valve C^1), channels b and c into chamber D^1. Plunger P^1 is moved to the left, forcing the water of chamber D^2 through channels d, e, ports f and g into outlet H. In the last third of the stroke, valve C^2 is shifted to the left, establishing communication between chambers B and E^2, through port k and channels l and m—and at the same time connecting chamber E^1 with outlet H through channels n and o and port p. Plunger P^2 is moved to the right, shifting, in the last third of its stroke, valve C^1, and thus establishing communication between chambers B and D^2 through port f and channels e and d.

The pistons are brought to rest at the end of the stroke by rubber seatings S^1, S^2.

Piston P^1 imparts a reciprocating motion to lever L, which, in combination with the movable pawl M, ratchet-wheel W, stationary pawl N, and index gear R, causes the dial hand U to register for each four plunger strokes (single strokes) $\frac{1}{30}$ of a cubic foot.

Fig. 1 is a section through u v (see figs. 2 and 3).

Fig. 2 is a section through w x (see figs. 1, 2 and 4_a).

Fig. 3 is a view from below with base plate (fig. 4_a) removed, showing the walls of chamber B partly in section.

Fig. 4_a is a top view of the base plate, showing valves, ports, etc.

Fig. 4_b is a plan of the valve ports, channels and outlet, showing how channel *o* passes under channel *b*, channel *e* under channel *l*, etc.

*Description of the Kennedy Piston Water Meter** (see figures 5, 6, 7).—The measuring cylinder (*A*) forms the base of the meter, and is fitted with a piston (*B*) made of vulcanite. The piston is made to move perfectly water-tight and almost free from friction, by means of a solid cylindrical ring (*C*) of pure "Para" rubber, which rolls between the body of the piston and the internal surface of the cylinder. Each end of the cylinder is fitted with an india rubber seating (*D*), on which the piston will form a water-tight joint, if back pressure should force it to either end of the cylinder; undue pressure is thus prevented from being thrown on the piston roller.

The piston rod (*E*), after passing through a stuffing box (*F*) in the cylinder cover (*G*), is attached to a rack (*H*) which gears into a pinion (*K*) fixed on the shaft (*L*). The shaft is turned in reverse directions, actuating the reversing and indexing gear (*M*) as the piston moves up and down. The rack is kept in gear and guided in a vertical line by an anti-friction roller, which is carried on a stud projecting from one of the shaft-bearing brackets. The cock-key (*P*), which directs the water alternately above and below the piston, is placed in the same axial line as the shaft, and is fitted with a duplex lever (*Q*) which is actuated by a weighted lever (*R*) carried loosely on the shaft, and caused to fall alternately on each arm of the duplex lever. The weighted lever, after reversing the key, falls on a buffer (*S*) faced with india rubber, which, yielding before it and traveling in the same curve, gradually brings it to rest.

Fig 5 is a side section through the center shaft, cock-key, and piston.

Fig. 6 is a front section of cock-key (*P*) and water passages (*U*, inlet, and *V*, outlet).

Fig. 7 is a horizontal section through line *UV*.

The meter is shown in the position of having nearly completed

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*Description and figures are taken with but slight changes from the circular of the Kennedy Patent W. M. Co., Kilmarnock, Scotland.

its upward stroke. The water enters at the inlet (*U*), and is directed by the cock-key down the passage (*W*) to the bottom of the cylinder, forcing up the piston, which presses the water (which on the previous down-stroke entered above the piston,) up through passage (*X*), passing behind passage (*V*), and is directed by the cock-key into the outlet passage (*V*). When the piston has moved up a little farther, the bob (weighted lever *R*) will pass its point of unstable equilibrium and fall on the key arm (arm of duplex lever *Q*) which it will send down until it is stopped by the buffer box (*S*). The key will then be at right angles to its position as shown in fig. 6. The water will then be directed from *U* down *X* into the top of the cylinder, forcing the piston down, while the water admitted below during the last stroke is forced up the passage *W* and out by the outlet *V*. When the piston has arrived near the bottom of the cylinder, the lifter will have lifted the bob from the left side of the buffer-box and raised it to the point of unstable equilibrium; from there it will have fallen on the right hand key-arm, and have brought back the cock-key to its former position, ready to begin another upward stroke.

It is unnecessary to illustrate here the method of converting the reciprocating motion of the shaft (*L*) into the circular motion (in one direction) of the index wheels (*M*), and thus causing to be registered a quantity approximately proportional to the distance traveled by the piston.*

Velocity Meters.—In the velocity meters of the Siemens system a small wheel is driven by the passing water, and the number of revolutions is the measure of the quantity delivered. The frictional resistance, offered by the journals of the wheel spindle and the registering apparatus, cause important modifications of the velocity of the wheel. The Hesse meter practically overcomes the objectionable influence of this resistance, but it will be shown that, even if it could be wholly avoided, perfect accuracy of registration would not thereby be effected.

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*A raichet is interposed between the pinion and the registering gear, and the degree of approximation in indicating the "length of piston travel" depends upon the number of teeth in the ratchet.

*Description of the "English" Siemens Velocity Water Meter** (see figs. 8, 9).—Of the Siemens system there are two important forms, the one manufactured by Guest & Chrimes of Rotherham, England, and the other by Siemens & Halske of Berlin. The former will be termed the "English" Siemens, and the latter the "German" Siemens.

It will be seen from the figure of the English Siemens meter, that the water passes, as indicated by the arrows, from the inlet pipe through a funnel, into a small reaction wheel, or Barkers mill (*H*), (constituting the measuring drum,) causing it to revolve. The water then passes on to the outlet pipe. The motion imparted to the measuring drum is communicated to the index, and thus a quantity proportional to the number of revolutions of the drum, registered.

Fig. 8 is a perspective view of the drum or measuring medium (*H*), showing the adjusting or regulating vanes *a a a*, and curved water ways *b b b*.

Fig. 9 is a section of the meter, filter and unions complete. *A* is the inlet. *C* and *E* are filters for the purpose of preventing foreign substances from passing into the drum *H*. The motion of this drum is retarded and suitably regulated by the vanes *a a a*. *J* is an oil-box for the purpose of lubricating the spindle *K*. *N* is the outlet. *O* is the spindle of the drum, with screw *Q* attached for the purpose of giving motion to the wheels of the dial work *R*. *S S* is an oil chamber for the purpose of lubricating and protecting the dial wheels from the action of the water, etc.

Description of the "German" Siemens Velocity Water Meter† (see figs. 10, 11).—This meter differs from the "English" Siemens in so far as the motor is concerned, a small pressure wheel taking the place of the reaction wheel.

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* Description, in the main, and figures taken from the circular of Guest & Chrimes.

† The figures are taken from a valuable article, on the subject of water meters, in the German "*Civilingenieur*" of the year 1875, by B. Salbach, Kgl. Baurath at Dresden. At the instigation of the City Council of Dresden, an exhaustive set of tests were made of twelve "meters of the most modern construction"—among these the Kennedy, the "English" and the "German" Siemens. Further reference will be made to this article.

The water having entered the meter through the inlet pipe *U*, passes through the openings *a a a a*, in the brass casing *A*, and coming in contact with the buckets *b b b b*, imparts motion to the wheel. The water then escapes through openings *c c* and finally discharges into the outlet pipe *V*.

The manner in which the motion imparted to the wheel is transmitted to the index, is the same as in the "English" Siemens. In order to keep out the coarse sediment, the water is made to pass through a screen before entering the meter. For the purpose of regulating the velocity of the wheel, four small openings *e e e e* are bored into casing *A*, in a direction opposed to the motion of the wheel; and by closing or enlarging these, the velocity of the wheel may be increased or reduced.

The stationary ribs *d d* counteract in part the tendency of the water to rotate (see p. 105).

Description of the Hesse Velocity Water Meter (see figs. 12, 13, 14, 15, 16, 17, 18).—The water from the inlet pipe enters channel *A* (fig. 12), passes through openings *a a* (figs. 12, 13), and striking the buckets *b b* (figs. 12, 13) imparts motion to the measuring wheel—a pressure wheel similar in character to that of the "German" Siemens. The water passes then from the wheel chamber *B* into chamber *C*, mainly through valve opening *d* (fig. 12), and in part through chamber *e*, opening *f*, chamber *g*, and conical tube *h* (figs. 16, 17), and is finally discharged through chamber *D* into the outlet pipe.

The motion of the measuring wheel is transmitted to the worm wheel *H* (figs. 16, 17), by means of the endless screw *F* (fig. 16) which is attached to the upper end of the wheel spindle *G* (figs. 12, 16). This worm wheel, in revolving, interrupts intermittently the direct flow of that portion of the water which passes through chamber *g*. In the position of the worm wheel shown in fig. 16, the solid arm of the wheel (the cause of this interruption) is just passing the openings *f* and *h*, hence direct flow through these openings is just beginning. During the interval of direct flow the action is comparable to that of the jet pump, causing the pressure in chamber *g* to fall below that in chamber *C*. The interruption of the direct flow causes the pressure to rise above that in chamber *C*.

The alternating high and low pressures in chamber *g*, thus induced by the slow rotation of the worm wheel, cause the cap *K* of the bellows-like rubber diaphragm *E* (figs. 12, 16, 17) to rise and fall accordingly. The number of such pulsations or strokes is directly proportional to the number of rotations of the measuring wheel. The length of the stroke is limited by the heads of set screws *L L* (figs. 12, 16, 17).

This reciprocating motion of the cap *K* is transmitted and converted into the circular motion of the gear wheels of the index, through lever *M*, rock-shaft *N*, shaft *P*, lever *R*, pawl *S* and ratchet wheel *T* (figs. 12, 14, 15).

The dial hands are thus made to register a quantity, which is directly proportional to the number of revolutions of the measuring wheel. The measuring wheel is made of hard rubber of specific gravity 1.2, and with the cork attachment (*U**) has the same weight as an equal volume of water. There is then so little pressure upon the journals of the spindle *G*, that the frictional resistance offered is exceedingly small. The worm wheel *H* rests loosely in its bearings, offering but little resistance to rotation. Since in 38 revolutions of the measuring wheel, but one revolution is given to the worm wheel, the work and hence the effective resistance is minute. The frictional resistance due to the periodic pressure upon the journals of the wormwheel, as the arm passes opening *f*, was found by experiment to be very small.

When the meter is delivering water at rates above 3 or 4 gallons per minute, the valve *J* is lifted, but the difference of pressures in chambers *B* and *C* is far greater than that needed to operate the bellows. When the rate of delivery is small, the valve is seated, and the entire quantity is forced through chamber *g*, insuring the action of the bellows.

The alternate rise and fall of pressure in chamber *g*, furnish an abundant surplus of power to provide against undue resistance in the stuffing box *X* (fig. 12), and all differences due to the character of the workmanship, and to wear or corrosion of the parts of the registering apparatus.

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*The cork attachment is unnecessary, as the weight of the wheel in water is sufficiently small without it.

The measuring wheel does not supply the power expended in moving the registering apparatus, hence the unavoidable changes in the latter do not affect the accuracy of the meter. This points to the distinctive feature of the Hesse meter.

m. m. and *n. n.* (figs. 12, 13) are stationary ribs provided for the purpose of checking in part the rotation of the water in chamber *B*, and offering additional resistance to the motion of the wheel. Such resistance diminishes the detrimental influence of the solid friction (see p. 105), and causes almost immediate stoppage of the wheel in case the water is suddenly shut off.

The meter tested is provided with connections for $\frac{1}{2}$ inch pipe. Openings *a a* have $\frac{9}{32}$ inch diameter. Valve opening *d* has $\frac{5}{8}$ inch diameter. Weight of valve *J* is 0.16 lb. Entire weight of meter is 21.4 lbs.

Fig. 12 is a vertical section through *s t* (see fig. 14).

Fig. 13 is a horizontal section through *u v* (see fig. 12).

Fig. 14 is a top view of the meter with the dial box removed, showing the dials, etc.

Fig. 15 is a top view of that portion of the registering apparatus contained in chamber *C* (see fig. 12).

Fig. 16 is a vertical section of the bellows-like diaphragm etc., taken through *w x* (see fig. 15).

Fig. 17 is another vertical section of the same through *y z* (see fig. 15).

Fig. 18 is a section of the screen or filter which is interposed between the meter and the inlet pipe.

The material used in constructing the meter is shown by the manner of shading the sections. It may be found advantageous to make a different selection for some of the parts. The meter will not serve for the delivery of hot water without radical changes in the material.

The Kennedy and the Siemens Curves (see diagrams) were obtained from the experiments of Mr. Salbach (see foot note, p. 85), who used such curves as a means of comparison.

The volume of water delivered was measured in an accurately constructed tank. The loss of head was given by the difference

of the readings of two large quicksilver manometers, the one communicating with the inlet, and the other with the outlet pipe immediately adjacent to the meter.

Tests were made under mean heads* of about 45 and 150 feet. The change of mean head had no material effect upon the curves of registry of these meters, excepting in the case of the "German" Siemens meter II, which gave better results under the greater head, and even this was doubtless due to cleaning of the meter in the interval. The effect upon the curves of head lost was not important, and was probably due, as Mr. Salbach says, (mainly) to some imperfections in the manometers when under low pressure. The curves of registry were plotted from the tests made under the lower mean head, the curve from tests under the higher mean head being added for the "German" Siemens meter II—II_a lower, II_b higher mean head. The curves of head lost were plotted from the tests under the higher mean head.

The Worthington B, C and D curves of registry were plotted from the results of experiments conducted by Prof. Hesse, as chairman of a committee appointed by the Board of Managers the Twelfth Industrial Exhibition of the Mechanics' Institute 1878 (published in report). Meter *B* had never been in use, *C* had been in use 3 months, *D* 8 months. A number of others were tested showing the effect of wear, etc.

The Hesse and the Worthington A curves were plotted from the results of a set of tests conducted by the writer, with the assistance of Mr. H. Dikeman, a student of engineering in the University of California.

The Hesse meter tested, forms a part of some experimental apparatus in the Mechanical Laboratory.

The Worthington *A* is a $\frac{5}{8}$ inch meter which was specially selected by Mr. Purcell of the Oakland Water Co. to serve as a test meter.

The quantity of water delivered was weighed to $\frac{1}{10}$ lb., and

*It is presumed that by "mean head" is meant the average head in the inlet pipe.

the pressures measured by means of a sensitive gauge described in the *Mining and Scientific Press* of Sept. 2, 1882, also in *Bulletin No.* 1 of the College of Mechanics. With this gauge the heads could easily be measured to $\frac{1}{10}$ of a foot. The time was observed only to single seconds. The results of these tests are tabulated below. The diameters of the inlet and outlet pipes were the same at the points where connected with the pressure gauge, so that it was unnecessary to make allowance for the velocity heads at these points in order to obtain the effective difference of heads. The temperature of the water varied 2°F., averaging 55°F.

The possible error in these tests, it is thought, may be safely taken at 1 per cent. in the rate of delivery, at $\frac{1}{4}$ per cent. in the ratio of registered to actual delivery, and at one foot in head lost at high rates, and $\frac{2}{10}$ foot at low rates.

The Hesse meter, experimented with, had previously been subjected to various tests by the Oakland Water Co., and had delivered, during four months, 62,000 cubic feet (in great part at the rate of $12\frac{1}{2}$ gallons per minute), without being in the least damaged. This is a greater quantity than would be drawn in 5 years in the average service. However, it must be borne in mind that this test involved the important element of time, only to a small extent.

Tests of the accuracy and delivery of the Hesse one-half inch Meter.

No of Test.	Hydraulic Heads in feet.		Time in Sec's.	Weight in lbs. avoirdupois G.	Cubic Feet.		Rate of Delivery.		Head lost in feet, H-h.	Ratio of regist. to actual vol. in %.
	Inlet H.	Outlet h.			Actual $\frac{G}{62.4}$	registered.	Cub. ft. per sec.	Gals. per min.		
1	—	—	—	—	—	—	.00015	.07	—	—
2	59.85	59.40	1308	31.3	0.502	0.4	.00038	.17	.45	79.7
3	59.50	59.00	2543	72 2	1.157	1.0	.00046	.21	.50	86.4
4	59.00	58.15	3660	218.0	3.494	3.6	.00096	.43	.85	103.0
5	59.40	58.55	1392	119.8	1.920	2.0	.00138	.62	.85	104.2
6	59.40	58.45	1102	119 5	1.915	2.0	.00174	.78	.95	104.4
7	59.40	58.30	915	119.8	1.920	2.0	.00210	.94	1.10	104.2
8	59.20	58.05	802	120 0	1.923	2 0	.00240	1.08	1.15	104 0
9	59.10	57.90	1125	180.6	2.894	3.0	.00257	1.15	1.20	103.7
10	59.0	57.5	840	182.0	2 917	3.0	.00347	1.56	1.5	102.9
11	58.8	56.9	641	184.3	2.954	3.0	.00461	2.07	1.9	101 6
12	57.1	54.7	524	185.0	2.965	3.0	.00566	2.54	2.4	101.1
13	56 8	53.9	452	186.0	2.981	3.0	.00660	2.96	2 9	100.6
14	56.5	53.3	441	198.6	3.183	3 2	.00722	3.24	3.2	100.5
15	56.3	52.7	375	186 8	2.994	3.0	.00798	3.58	3.6	100.2
16	55.8	52 1	365	187.0	2.997	3.0	.00821	3.69	3.7	100.1
17	55.9	50.9	304	187.3	3.002	3.0	.00987	4 43	5.0	100.0
18	55.6	49.9	563	374.6	6.003	6.0	.01066	4.79	5.7	100.0
19	55.2	48.4	507	374.7	6.005	6.0	.01184	5.32	6.8	99 9
20	54.7	46.5	465	374.7	6.005	6.0	.01291	5.80	8.2	99.9
21	54.3	44.9	432	375.0	6.010	6.0	.01391	6.24	9.4	99.8
22	55.0	45.8	434	375.0	6.010	6 0	.01386	6.22	9.2	99.8
23	54.5	42.8	390	376.0	6.026	6.0	.01545	6 94	11.7	99.6
24	53.5	38.3	340	376 4	6.032	6.0	.01774	7.97	15 2	99.5
25	52.8	34.5	312	376 5	6.034	6.0	.01934	8.68	18.3	99.4
26	50.7	29.4	290	376.5	6.034	6.0	.02081	9.34	21.3	99.4
27	49.7	24.9	267	376.7	6.037	6.0	.02261	10.15	24 8	99 4
28	49.3	20.9	256	388.8	6.232	6.2	.02434	10.93	28.4	99.5
29	47.6	15.1	231	376.7	6.037	6.0	.02613	11.73	32.5	99 4
30	46.5	11.1	220	377.0	6.042	6.0	.02746	12.33	35.4	99.3
31	45.7	6.8	210	376.7	6.037	6.0	.02875	12.91	38.9	99.4

In test No. 1 the limit was reached.

Tests of the accuracy and delivery of the Worthington five-eighths inch Meter (A) *No.* 26,737.

No of Test.	Hydraulic Heads in feet. Inlet H.	Hydraulic Heads in feet. Outlet h.	Time in Sec's.	Weight in lbs. avoirdupois G.	Cubic Feet. Actual $\frac{G}{62.4}$	Cubic Feet. registered.	Rate of Delivery. Cub. ft. per sec.	Rate of Delivery. Gals. per min.	Head lost in feet, H-h.	Ratio of regist. to actual vol. in %.
1	——	——	——	——	——	——	.00015	.07	——	——
2	59.00	58.85	1622	17.0	.2724	.30	.00017	.08	.15	110.1
3	59.00	58.80	640	15.5	.2484	.27	.00039	.18	.20	107.0
4	58.85	58.40	492	59 4	.9519	1.00	.00193	.87	.45	105.1
5	58 65	57.00	379	122.0	1.9551	2.00	.00516	2.32	1.65	102.3
6	58.15	55.40	272	122.5	1.9631	2 00	.00722	3.24	2.75	101.9
7	57.30	52.20	308	184.4	2.9551	3.00	.00960	4.31	5.10	101.5
8	56.5	49.5	255	185.0	2.9647	3.00	.01163	5.22	7.00	101.2
9	53.8	40.4	302	310.7	4.9791	5.00	.01649	7 40	13.40	100.4
10	49.1	24.9	224	313.8	5.0288	5.00	.02245	10.08	24.20	99.4
11	43.7	8.1	184	316.3	5.0689	5.00	.02755	12.37	35.60	98.6

Discussion of the curves of head lost.—These are approximately parabolic, and may be represented roughly by the equation $H - h = A + B\,Q^2$, wherein Q is the quantity delivered in cubic feet per second, A and B constants. In the Worthington $\frac{5}{8}$ inch $A = 0.4$, $B = 46{,}000$.

These curves simply serve the purpose of determining the deliveries of the several meters, prior to making comparisons of sensitiveness, cost, &c. By following the 20 feet line it will be seen that with this loss of head the Worthington $\frac{5}{8}$ inch delivers 9.1 gallons per minute, the Hesse $\frac{1}{2}$ inch 9.1, the English Siemens 1 inch 18.5; the German Siemens 1 inch 25.1, the Kennedy 1 inch 32.0. If then the delivery of the Worthington $\frac{5}{8}$ inch, under effective head of twenty feet,* is adopted as unit, we have: Worthington $\frac{5}{8}''$...1, Hesse $\frac{1}{2}''$....1. English Siemens 1″....2, German Siemens 1″....$2\frac{3}{4}$, Kennedy 1″....$3\frac{1}{2}$.

It would have been of great advantage in making the comparisons which follow, could the sizes of the several meters

*The velocity head in the $\frac{5}{8}$ inch outlet is small, and is therefore neglected.

have been so selected as to make the deliveries the same under the same effective head.

Discussion of the Curves of Registry. The notable properties of these curves are to be found in the degree of approximation to parallelism of the horizontal sweep to the axis of abscissæ, and in the proximity of the vertical sweep to the axis of ordinates. the former furnishes the true criterion for estimating the degree of accuracy which may be reached by adjustment, the latter indicates the degree of sensitiveness of the meter.

These curves may be shifted up or down, or the curves remaining stationary, the 100% lines may be so shifted by a simple adjustment of the meter. This may be effected, in each of the meters, by changing the number of teeth in one or more of the gear wheels leading to the index, since this number determines the ratio of the movements of the dial hands to the movements of the pistons in the piston meters, and of the measuring wheels in the velocity meters.

Such a change may be effected also, though to a smaller extent, as follows:

In the Worthington, by adjustment of the length of stroke.

In the English Siemens, by change of the regulating vanes *a a a*.

In the German Siemens, by increase of the openings *a a a a* or *e e e e*, or by change of the buckets.

In the Hesse, by change of the number of teeth in worm wheel *H*, or by increase in size of openings *a a*, or by change of the buckets or stationary ribs.

An inspection of the curves will bring out some marked features.

The *Worthington curve*, for quantities above 3 gallons per minute, becomes practically a right line, strongly inclined to the axis of abscissæ, showing at low rates too great, and at high rates too small a registry. This is doubtless due, in the main, to the differences in length of stroke. This stroke is on the average a little above two inches. A $\frac{5}{8}$ inch rubber seating is compressed at each end of the stroke by an amount, increasing

with the momentum or with the velocity of the piston, hence with the rate of delivery. If the difference in the magnitude of this compression, between rates of 3 and 15 gallons per minute, is $\frac{1}{16}$ inch each seating, there results $\frac{1}{8}$ inch difference in length of stroke. The meter registers the number of strokes, hence, if adjusted to register correctly at rate of 3 gallons, it will register about $\frac{\frac{1}{8}}{2} = 6$ % too little at rate of 15 gallons per minute.

As the rate becomes less than 3 gallons per minute, the diminution in length of stroke is more marked.

The Kennedy curve, when compared with the Worthington, shows the advantage of registering the approximate distance traveled by the piston, in place of the number of strokes, the main sweep being practically parallel to the axis of abscissæ. By proper adjustment, i. e., by shifting the 100% line upward 1.05% (see dotted line), this curve is made almost perfect.

The Siemens curves were improved by adjustment (see dotted lines). They show inferiority in point of sensitiveness. This is due to the resistances of solid friction opposing the motion of the measuring wheels.

The Hesse curve shows a favorable adjustment, and a degree of sensitiveness nearly equal to that of the best piston meters. The effect of solid friction is not observable for quantities exceeding one gallon per minute. The curve, following the law of combined fluid pressure and resistance, rises rapidly for quantities less than 4 gallons per minute. If there were absolutely no solid frictional resistance, the curve would mount to a great height as the quantity approached zero—see considerations which led to the adoption of the form of measuring wheel, page 101.

Comparison.—The meters described will be compared with reference to the considerations enumerated on page 78.

1st, The accuracy will primarily be compared by means of the adjusted curves, and without reference to permanency. Such comparison shows the Kennedy curve to be without doubt the best; then follow in order the Hesse, the Worthington *A* and *B*, the German Siemens, the English Siemens, the Worthington *D*.

2nd, The necessity of special adjustment is greater in the

Worthington than in the Kennedy, in the Siemens than in the Hesse. A close comparison is difficult without the experience of the manufacturers; it is apparent however from the curve, that even the Kennedy requires a special adjustment if great accuracy is sought.

3d, The difficulty of special adjustment is greater than it should be, in each of the meters excepting the Worthington. Provision should be made for these adjustments outside of the casing. In the Hesse meter, for instance, this might be effected by suitable provision for shifting of one or more of the stationary ribs. The Worthington is easily adjusted by tightening or loosening the screws of the cap, covering one of the rubber seatings.

4th. A certain degree of sensitiveness is important. This is apparent from the fact that one gallon in three minutes can be made to supply a household by use of a small storage tank. The Kennedy 1″ will register a gallon in from 20 to 30 minutes; the Worthington $\frac{5}{8}$″ and the Hesse $\frac{1}{2}$″, a gallon in 15 minutes; the two one inch Siemens meters a gallon in from 1 to $1\frac{1}{2}$ minutes. A direct comparison of these figures would not be fair to the Siemens meters, as the deliveries (under given head) of the sizes tested were greater than those of the Worthington and the Hesse. However it is safe to say that the Siemens meters are much inferior in point of sensitiveness. The wear of the Worthington piston will cause deterioration in this respect, unless the meter is judiciously used.

The sensitiveness of the Hesse meter may be greatly increased, but at the expense of the accuracy at small rates of delivery—see page 105. However, a rate of one gallon in 15 minutes or 96 gallons in 24 hours, is about the minimum rate admitted in Providence, R. I., and only $\frac{1}{4}$ of the quantity passed in the average service. Such a degree of sensitiveness makes theft out of the question.

5th. With respect to permanency of sensitiveness and accuracy, it is confidently thought that the Hesse meter will stand foremost under a wide variation of wear etc. There is no leak-

age due to wear of valves and piston, no alteration due to change of friction by wear, rusting, or oiling of the registering apparatus. The only parts which might be regarded as sensitive in this respect, are the circular openings *a a*; but as these are made of hard rubber, no rusting can take place, and any tendency towards diminution in size of these openings, by deposition of sediment, is overcome by the rapid flow of water. Little of the wear which may take place in the meter is of a nature to affect its curve of registry.

It is probable that the Kennedy curve is reasonably permanent.

The effect of wear, upon the Worthington curve, is plainly shown by comparison of curves *B*, *C* and *D*. It must be remarked, however, that it is unfair to charge against this meter a deterioriation which appears to be due to over taxation. The manufacturing company calls special attention to the fact that their $\frac{5}{8}$ inch meter should not be taxed with a delivery greater than $7\frac{1}{2}$ gallons per minute. This corresponds to an effective head of about 16 feet. In San Francisco, where the hydrostatic head runs up to two hundred and fifty feet and more, it does not seem likely that the $\frac{5}{8}''$ Worthington is large enough for the average service.

That the Siemens curves are not particularly permanent is plain from the fact already mentioned, viz: that the accuracy and sensitiveness depend upon the magnitude of the frictional resistance of the indicating apparatus, and this will vary constantly with rusting, wear, etc. Mr. Salbach, who has given the German Siemens meter careful consideration, says it is capable of giving good results in every respect when new, but after a while the meter will deteriorate in so far as the accuracy is concerned in the measurement of quantities at small rate of flow. "The main cause," he further says, "is the oil which is contained in the first chamber above the wheel, and which in time adheres to the gear wheels. A further detrimental effect is produced by freezing or thickening of the oil in case the temperature sinks to 2 or 3° C. From these facts it is plain that the oil chamber is a bad feature of this meter, and one that there

should be an energetic effort made to overcome." This has been effected in the Hesse Meter.

6th. The liability to obstruction was not tested in the Worthington and Hesse meters, as similar data was wanting in connection with the others. A suitable screen (see figs. 9 and 18) should be provided for each meter to keep out the coarser obstructions such as leaves, straw, chips of wood, wads of oakum, etc., which are easily withheld. The liability to obstruction is said to be a weak feature of some of the rotary piston meters, but not of the oscillating. To be sure a sandy deposit in the measuring cylinder will cause rapid wear in the Worthington, and a certain resistance to free rolling of the rubber ring in the Kennedy; but with reasonably clear water no serious difficulty seems likely to occur if the coarser obstructions are screened, and thus wedging of valves prevented. The sandy or muddy sediment is probably less detrimental to the velocity meters when properly constructed. It is suggested that the cylindrical wheel chamber in Hesse's meter should be extended a few inches in length and provided with a waste cock at the bottom, for convenient discharge of accumulated sediment, in case it should be used for the measurement of muddy water.

7th. The greatest advisable rate of delivery is least in the Worthington, and most in the velocity meters. As already stated the Worthington is not guaranteed for an effective head exceeding 16 or 20 feet, corresponding to a delivery of $7\frac{1}{2}$ gallons per minute by the $\frac{5}{8}''$, 15 gallons by the $\frac{3}{4}''$, etc. The safe limit of effective head in the Kennedy is, according to the manufacturer's statement, about 60 feet, the $\frac{3}{8}''$ delivering 20 gallons per minute, the $\frac{1}{2}''$ 30 gallons, the $1''$ 70 gallons, etc.

In the velocity meters the limit of head is exceedingly high. In the Hesse meter this limit is dependent almost solely upon the action of the rubber diaphragm. The difference of heads in chambers *B* and *C*, measuring about twice the effective pressure upon the diaphragm, will depend upon the square of the ratio of areas of the valve opening *d* and jet openings *a a*. In the meter tested the diaphragm is subjected to but $\frac{1}{20}$ of the total pressure lost in the meter, and this may be diminished at

will by simple enlargement of the valve opening. By closing the opening *h* and fastening down the valve, the diaphragm was subjected to 25 feet of pressure without damage. The diaphragm then would not give way under a total loss of head in the meter of $25 \times 20 = 500$ feet. The further question which must be considered, is; will the bellows operate under the rapid motion of the worm wheel due to high loss of head? A greater head than 60 feet was not available for trial, but in this case the time occupied in lifting cap *K* was only one-half the interval of high pressure. If the velocity of registering should be too great under very high heads, the difficulty is simply remedied by increasing the width of the arm, or the number of teeth, in the worm wheel. It is not thought that this would be necessary as the rate of supply of water to the bellows chamber is nearly proportional to the velocity of the measuring wheel.

8th. The compactness of the velocity meter is great as compared with that of the oscillating piston meter. This will appear from a comparison of the weights of meters of about the same delivery. See table, page 100.

9th. The prices are given, as near as possible, in the table, page 100. The price, as well as weight, increases much more rapidly with increase of delivery under the same head, in the piston meters, than of the velocity meters. In either form, the price increases at a smaller rate than the delivery. For example, a Kennedy 1 inch meter, delivering 4 times as much as the $\frac{3}{8}$ inch, costs less than $2\frac{1}{2}$ times as much; the English Siemens $1\frac{1}{2}$ inch, delivering 5 times as much as the $\frac{3}{4}$ inch, costs less than twice as much. Any comparison therefore of the price of meters of different delivery should be made with caution. The fallacy is apparent in the claim made by the Kennedy Co. to the effect that their 1 inch meter, delivering 2.02 times as much as the Siemens 1 inch, has over double the proportionate money value, and as it costs but 1.63 times as much as the Siemens, is therefore $\frac{2.02}{1} \frac{-1.63}{63} = 24$ % cheaper. Reference to the table will show that the Kennedy $\frac{1}{2}$ inch, delivering less than the Siemens 1 inch, costs considerably more.

The prices may be compared as follows:

(*a.*) Upon the basis of equal delivery, the list shows the Worthington to be cheaper for small sizes than the Kennedy or Siemens. As the deliveries increase, the Siemens become cheaper than the Worthington or Kennedy. The price of the Hesse has not been definitely ascertained.

(*b.*) Upon the basis of greatest advisable rate of delivery, the velocity meters are by far the cheapest, and the Worthington the most expensive. This is an important consideration only where there is on hand an abundant surplus of head for the house service. If, for example, the head is such as to make the capacity of the service pipe 10 or 12 gallons per minute, it becomes advisable to employ a $\frac{3}{4}$ inch Worthington, whereas a Siemens of far less delivery, or a $\frac{1}{2}$ inch Hesse meter will amply serve.

10th. The expense of repairs of the English Siemens meter is permanently guaranteed by the Manufacturing Co. for 5 % annually upon the original cost. The actual expense in this and the Kennedy, seems to be in the neighborhood of 3 or 4 % per annum upon the original cost. It is claimed that the average life of the rubber roller in the Kennedy is more than three years. If the Worthington is overtaxed, the wear of the piston, etc., will necessitate expensive repairs in order to maintain its sensitiveness.

In the Hesse meter the life of the rubber diaphram remains to be ascertained. It is known that pure rubber will deteriorate quite rapidly when exposed to air and light; but it is claimed that in cool water, under the exclusion of light and air, it will remain intact for an indefinite period. The rubber diaphragm is not taxed as is the roller of the Kennedy. There was scarcely a perceptible wear in the Hesse meter during the passage of 62,000 cubic feet of water. The velocity of the measuring wheel (380 revolutions per cubic foot) is far less than in the Siemens meters of equal capacity, and its weight is trifling. The spindle does not pass through a stuffing box. The shaft *P*, which does pass through a stuffing box, makes only $\frac{1}{6}$ revolution for each $\frac{1}{10}$ cubic foot registered.

Table of Deliveries, Greatest Advisable Rates of Delivery, Weights and Prices of Meters.

Name of Meter.	Size of in- and out-let. inches.	Delivery unit 9 gals. per min. under eff. head of 20 feet.	Greatest Advisable		Weight in lbs. avoirdu-pois.	Price $
			Rate of delivery in gals. per min.	Effective head in feet.		
Worthington. . .	$\frac{5}{8}$	1.0	7.5	16	59	17.00
	$\frac{3}{4}$	?	15.0	———	103	27.00
	1	?	30.0	———	175	33 00
*Kennedy	$\frac{3}{8}$	1.3	19.9	60	104	19.36
	$\frac{1}{2}$	1 8	30.0	———	162	27.83
	$\frac{3}{4}$	2.8	50.0	———	206	33.82
	1	5.4	70.0	———	322	46 00
	$1\frac{1}{2}$	11.0	150.0	———	564	75.00
English Siemens.	$\frac{3}{8}$	.2	* *	* *	?	12.10
	$\frac{1}{2}$	.5	———	———	?	14.76
	$\frac{3}{4}$	.8	———	———	?	18.15
	1	2.0	———	———	?	21.30
	$1\frac{1}{4}$	2.9	———	———	?	26.86
	$1\frac{1}{2}$	4.1	———	———	?	30.75
German Siemens.	1	2.5	———	———	33	26.00
Hesse	$\frac{1}{2}$	1.0	———	———	21	* * *

* The deliveries and greatest advisable effective heads in the Kennedy and English Siemens meters, were calculated from data furnished by the manufacturers' circulars. The Kennedy $\frac{1}{4}$ inch meter is omitted as it is not recommended by the manufacturing Co.

* * The greatest advisable effective head is many times greater in the velocity than in the piston meters.

* * * A careful estimate of the cost of manufacture of the Hesse meter, indicates a price considerably less than that of any other meter named.

Conclusion.—The following is an attempt to rank the meters according to their merits with respect to the more definite of the considerations enumerated. This is done with a certain reserve, as, in some cases, the information at hand is not sufficiently complete to admit of positive conclusions. Where two meters are placed in the same vertical column no comparison between them is attempted.

1.	Accuracy	K.	H.	$W_{(A)}$.	S.	$W_{(D)}$.
2.	Sensitiveness	K.	$W_{(A)}$. H.		S. $W_{(D)}$.	
3.	Permanency	H.	K.	S. W.		
4.	Greatest advisable rate of delivery	S. H.	K.	W.		
5.	Compactness	S. H.	W.	K.		
6.	Price—(*a*). Upon basis of equal delivery under the same head	H	W. S.	K.		
	(*b*). Upon basis of greatest advisable rate of delivery	S. H.	K.	W.		
7.	Expense of repairs	H.	S. K. W.			

The Worthington, though sufficiently accurate, and quite sensitive when new, has very small advisable rate of delivery, and unless judiciously used is subject to deterioration with respect to sensitiveness.

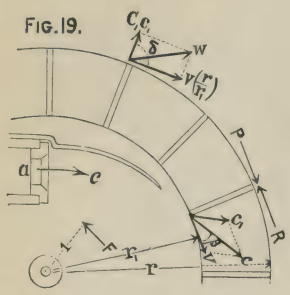
The Kennedy, while extremely accurate and sensitive, and an excellent meter in other respects, is the heaviest and most expensive.

The Siemens meters are very compact and admit of a high effective head without damage; but, while their accuracy is sufficient for considerable rates of delivery, they are inferior in point of sensitiveness.

The Hesse meter combines, in the main, the good features of the others, with an advantage in respect to permanency of sensitiveness, price and wear.

Construction of the Hesse Measuring Wheel.—The following is an abstract of the statement made by Prof. Hesse with regard to the considerations which led him to the present construction of the measuring wheel, and the introduction of the stationary ribs.

FIG. 19.



A is the area of opening, a.

r, the radius of the wheel.

v, the velocity of the wheel.

c, the velocity of the water in passing opening a.

P, the effective pressure (reduced to radius r) of the jet upon the wheel, including all pressures, positive or negative, directly due to the action of the jet.

R, the resistance (reduced to radius r) caused by the displacement of the mass of the water.

F, the solid frictional resistance (reduced to radius 1), offered by the spindle journals and the worm wheel.

M and N, constant coëfficients of pressure and resistance.

For permanent (uniform) motion of the wheel—

$$P = R + \frac{F}{r} \qquad (1)$$

The actual quantity of water delivered, $Q = Ac$.

The quantity registered, $Q^1 = Bv$, wherein B is a constant determined by the gearing, etc.

The ordinate in the curve of registry, $\frac{Q^1}{Q} = \frac{Bv}{Ac}$, is dependent upon P, R and $\frac{F}{r}$

On account of the variability in the workmanship and degree of wear, etc., upon the spindle journals and the worm wheel, the magnitude of F is subject to an unavoidable fluctuation of say 50%. Therefore, by diminishing the influence of F upon $\frac{v}{c}$ the permanency of the curve of registry is increased. It is evident also that, by diminishing the value of $\frac{F}{r}$, the Q necessary to move the wheel is lessened, *i. e.* the meter is made more sensitive.

In order to show that velocity meters of this and similar forms are practicable, it is only necessary to point out that $\frac{v}{c}$ is approxi-

mately constant. If this ratio were strictly constant, such a value of B could be reached by adjustment, as to make $\frac{Bv}{Ac} = 1$, and the meter would be perfectly accurate.

If the losses of head are assumed to be proportional to the squares of velocities, actual and relative, then

$$P\left(\frac{r}{r_1}\right) v = \frac{Q\gamma}{2g}\left(c^2 - Cc_1^2 - w^2\right),$$

wherein γ is the weight of unit volume of water, C a constant, c_1 the relative velocity of the water to the bucket, w the actual velocity of discharge. See fig. 19. $Q = Ac$.

$$c_1^2 = c^2 + v^2 - 2vc \cos \beta = c^2 \varphi_1 \left(\frac{v}{c}\right),$$

wherein φ_1 denotes a function.

$$w^2 = C_1^2 c_1^2 + \left(\frac{r}{r_1}\right)^2 v^2 - 2 (\cos \delta) \left(\frac{r}{r_1}\right) C_1 vc_1$$

Hence by transformation

$$P = \frac{A\gamma}{2g}\left(\frac{r_1}{r}\right)\left[c^2\left(\frac{c}{v}\right) - c^2 \varphi_2\left(\frac{v}{c}\right) - c^2 \varphi_3\left(\frac{v}{c}\right) - c^2 \varphi_4\left(\frac{v}{c}\right)\right]$$

or

$$P = M c^2 \varphi\left(\frac{v}{c}\right) \qquad (2)$$

Wherein the function of the ratio of velocities, $\varphi\left(\frac{v}{c}\right)$, increases with decrease of v—*i. e.* the pressure upon the wheel increases when c remains constant and the velocity of the bucket, v, is forcibly diminished.

$$R = N v^2$$

For $F = o$, by introducing values of P and R into equation (1).

$$M c^2 \varphi\left(\frac{v}{c}\right) = N v^2,$$

$$\frac{M}{N} \varphi\left(\frac{v}{c}\right) = \left(\frac{v}{c}\right)^2.$$

If then P were strictly proportional to c^2 and $\varphi\left(\frac{v}{c}\right)$, $\frac{v}{c}$ would be a constant for $F = o$.

However. the adopted law of loss of heads is a good approximation for considerable velocities only, therefore the result obtained indicates simply that, if the influence of F could be overcome, $\frac{v}{c}$ would not vary to any great extent, excepting for small rates of delivery.

The actual curve of registry, for $F = o$, is doubtless similar to that shown in fig. 20.

For any value of F (see equation 1)—

$$P = N v^2 + \frac{F}{r},$$

$$v^2 = \frac{P}{N}\left(1 - \frac{F}{rP}\right)$$

The ordinate in the curve of registry—

$$\frac{Bv}{Ac} = \frac{B}{Ac}\sqrt{\frac{P}{N}\left(1 - \frac{F}{rP}\right)}$$

This approaches the condition $F = o$, and the influence of a 50% fluctuation of F is the less, as the value of $\frac{F}{rP}$ is diminished, —*i. e.* as F is diminished, or as r and P are increased.

It appears from the above that the meter will gain in sensitiveness and permanency:

(I) by diminution of the solid frictional resistance (F);

(II) by increase of the radius (r) of the measuring wheel;

(III) by increase of the pressure (P) of the jet upon the wheel.

This increase of P may be effected:

(1) by reducing the area of the openings a a; *

* This is a convenient method of improving the curve of registry, but is limited in its application on account of the corresponding reduction of the delivery of the meter under a given head.

(2) by increasing the resistance (R) of the water, and thus reducing the velocity (v) of the wheel. This increase of R is accomplished:

(a) by increasing the area of the bucket, *i. e.* the effective displacing area;

(b) by introducing stationary ribs, and thus checking in part the rotation of the body of water in the measuring chamber.

In one wheel tested, a high degree of sensitiveness was reached, by curving that portion of the bucket encountered by the jet, and arranging for outer feed, thus greatly increasing the pressure. However, such refinement was found unnecessary, and the small addition to the expense was not deemed advisable.

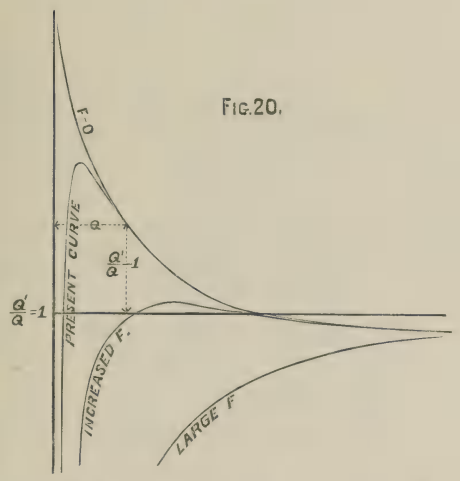


FIG. 20.

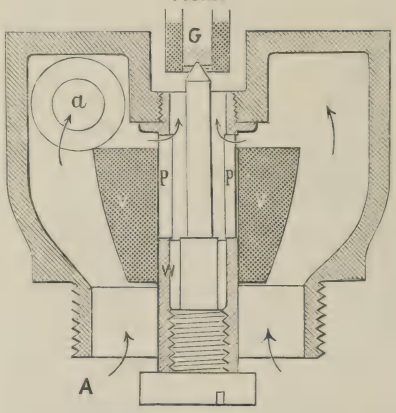
Due regard to the considerations enumerated, has led to sufficient sensitiveness and a high degree of permanency.

Improvement of the Curve of Registry.—There remains to be considered the question of a further improvement of the curve of registry. An immediate improvement of that portion of the curve corresponding to values of Q between 1 and 4 gallons per minute, may be effected by a small increase of F (see fig. 20);

but it must be borne in mind that such increase of F is necessarily accompanied by a considerable loss in sensitiveness.

Prof. Hesse devised the attachment shown in fig. 21, with which the curve of registry was perfected without sacrifice of sensitiveness. The light hard-rubber valve V slips freely upon the outer surface of the tube W. If Q is considerable, say 6 gallons or more per minute, the valve V is lifted to its highest position and no water can escape through the openings $p\ p$. If Q, hence the effective head, is less, the valve will occupy a lower position of equilibrium, and a small portion of the water will escape through the openings $p\ p$ without assisting in the rotation of the wheel. Thus $\frac{Q^1}{Q}$ may be reduced more and more as Q becomes smaller. This reduction is experimentally regulated by the width of the openings $p\ p$, and by the curvature of the surface of valve V.

FIG. 21.



This is important in connection with a test meter only. The present curve of registry is all that may be desired in a house meter, and certainly no device should be attached to the meter which would detract from the permanency or add to the liability to obstruction.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II — MARCH, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

March 6, 1885.

President Mendell in the Chair.

The President announced the election of the following members:

Chalmers Scott, John Hays Hammond, Hermann Krusi and John Richards.

Ross E. Browne read a paper on "Water Meters."

Mr. Specht gave notice of the following amendment to Article I, Section 2, of the By-Laws:

To omit the words "at 7.30 P. M. from September 1st to May 1st, and at 8 P. M. during the remainder of the year," and to substitute the words "at 8 P. M."

FIG. 4a.

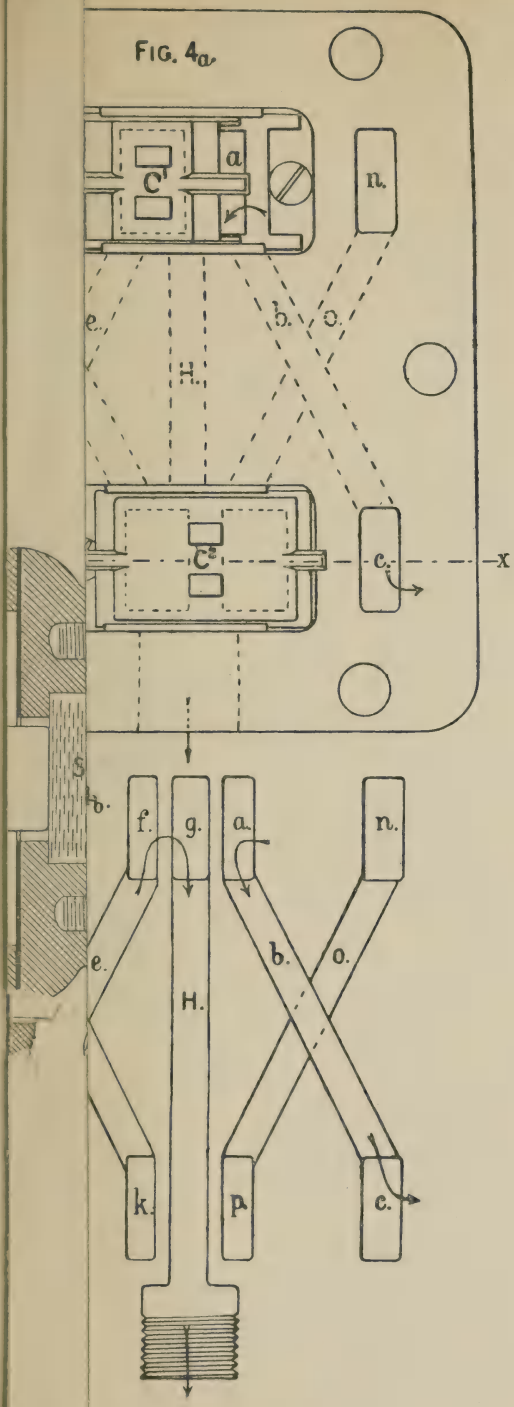


PLATE No. IV.

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Vol. II, No. XVII.

Browne on Water Meters.

WORTHINGTON METER

⅝ INCH

SCALE ½

Fig. 1.

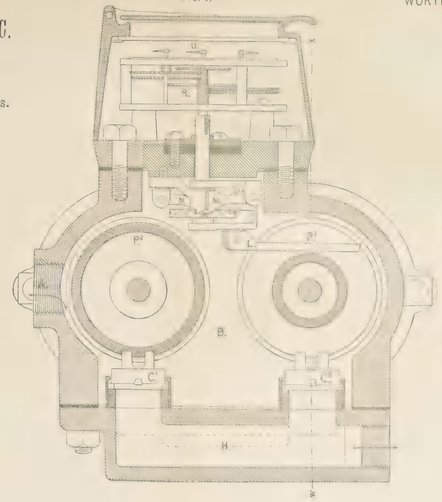


Fig. 2.

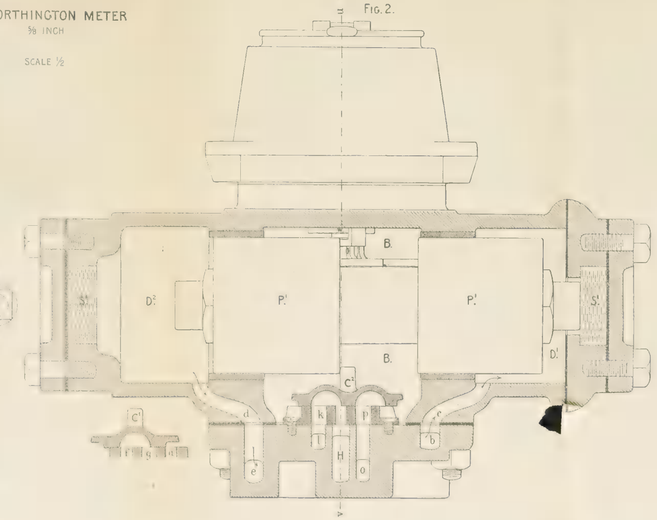


Fig. 3.

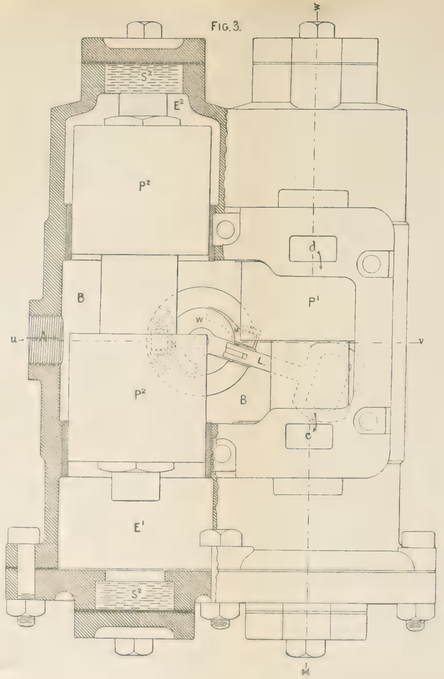


Fig. 4a.

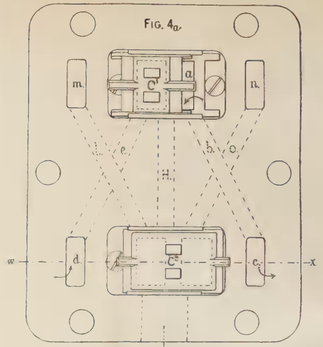
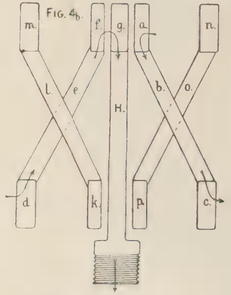


Fig. 4b



METER

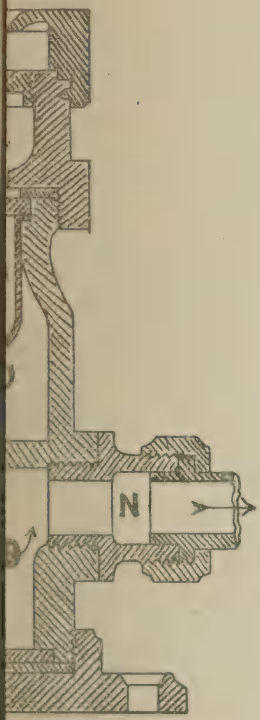


PLATE No. V.

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Vol. II, No. XVII.

Browne on Water Meters.

KENNEDY METER

FIG. 5.

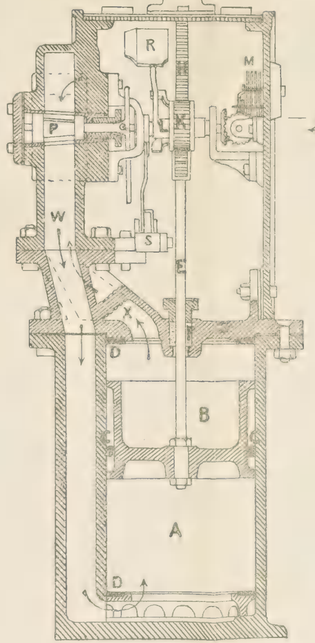


FIG. 6.

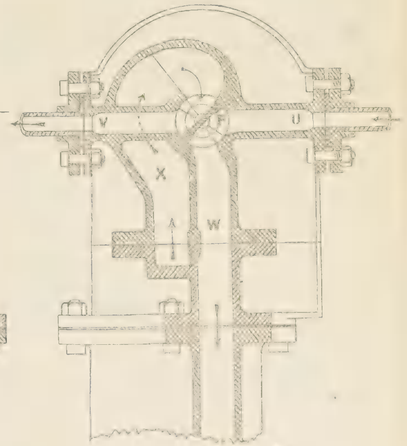
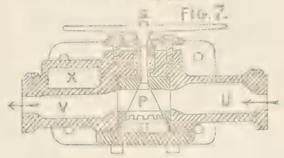


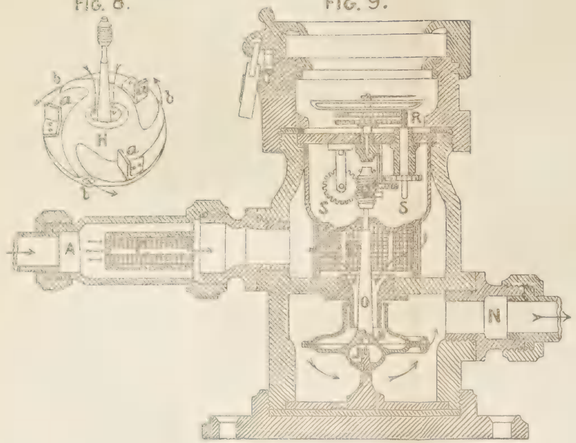
FIG. 7.



ENGLISH SIEMENS METER

FIG. 8.

FIG. 9.



GERMAN SIEMENS METER

FIG. 10.

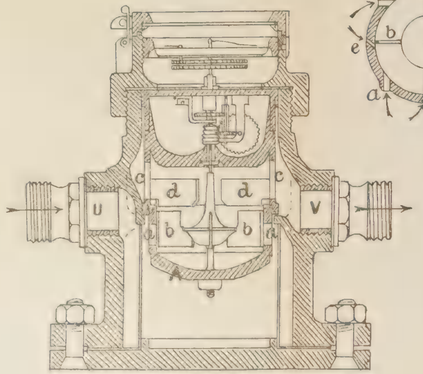
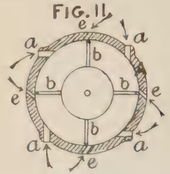
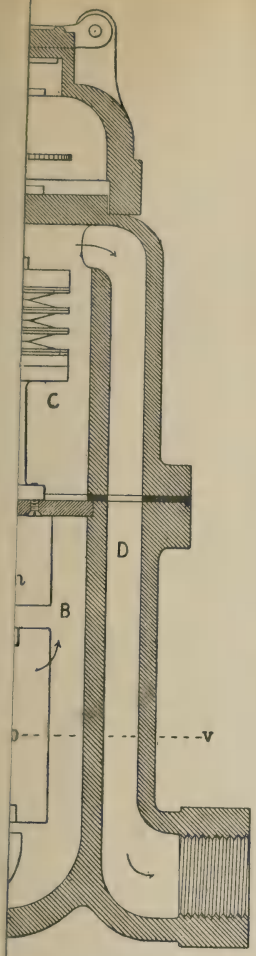
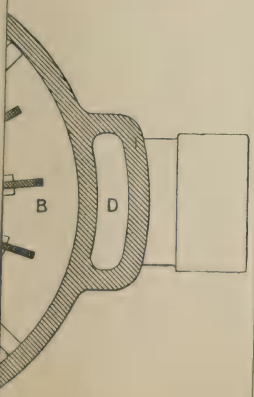


FIG. 11.





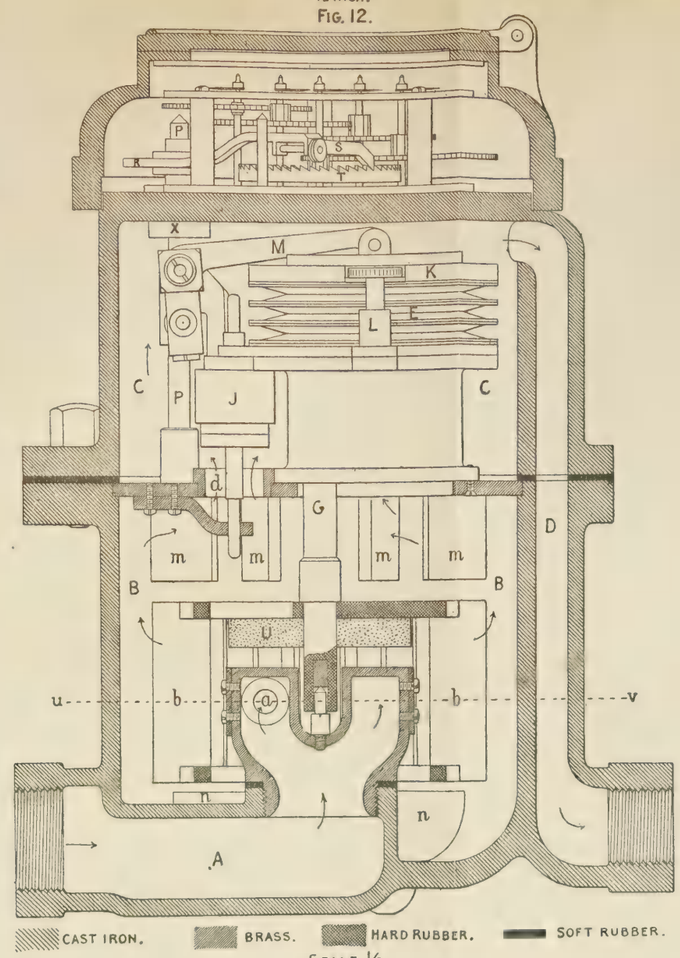
ER. SOFT RUBBER.



HESSE METER.

½ INCH.

FIG. 12.



SCALE ½.

FIG. 16.

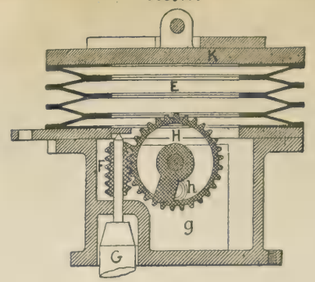


FIG. 17.

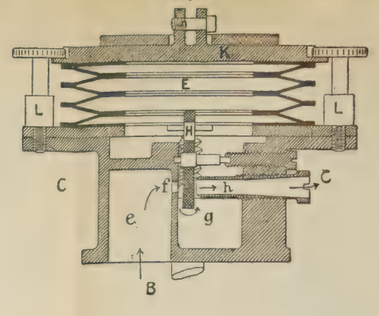


FIG. 15.

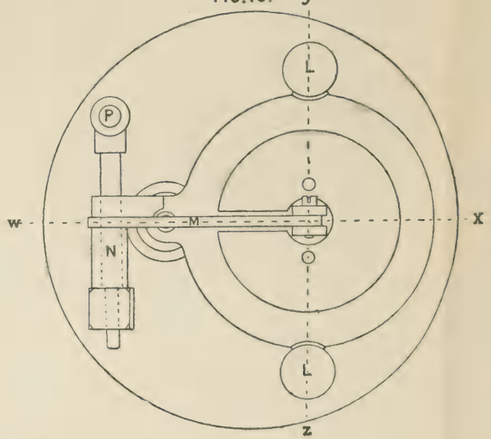


FIG. 18.

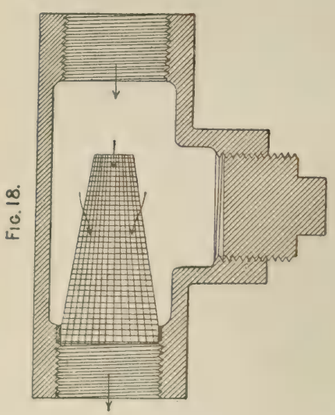


FIG. 14.

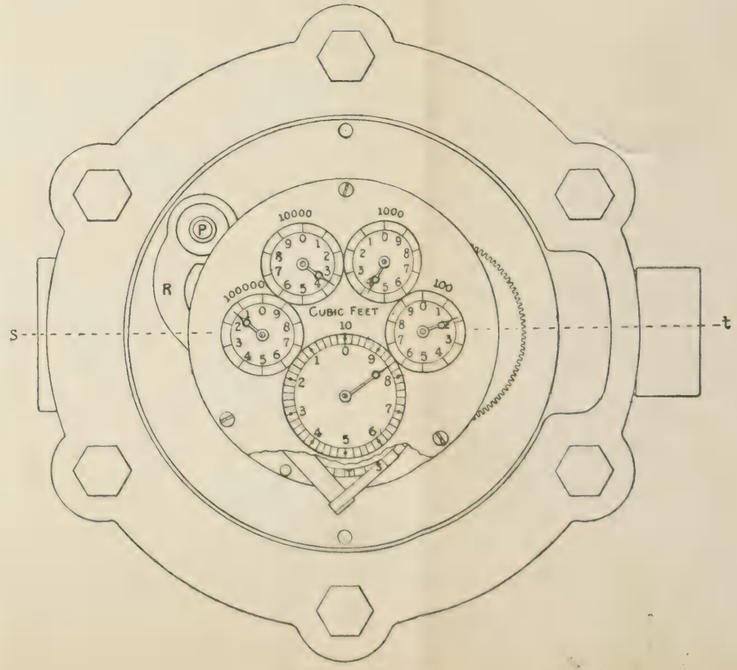
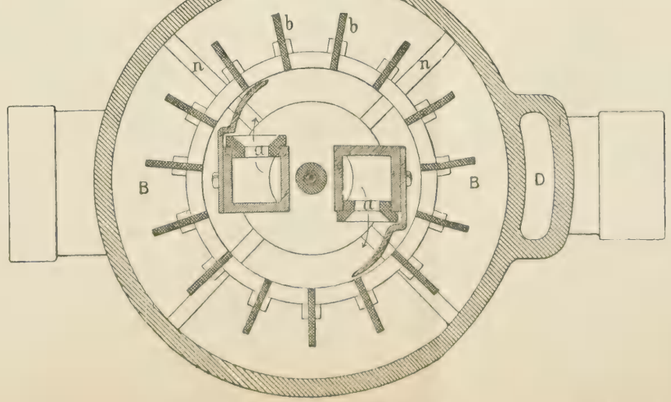


FIG. 13.



C
D
B
SOFT
B
D

PLATE No. VI.

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Browne on Water Meters.

HESSE METER.

½ INCH.

FIG. 12.

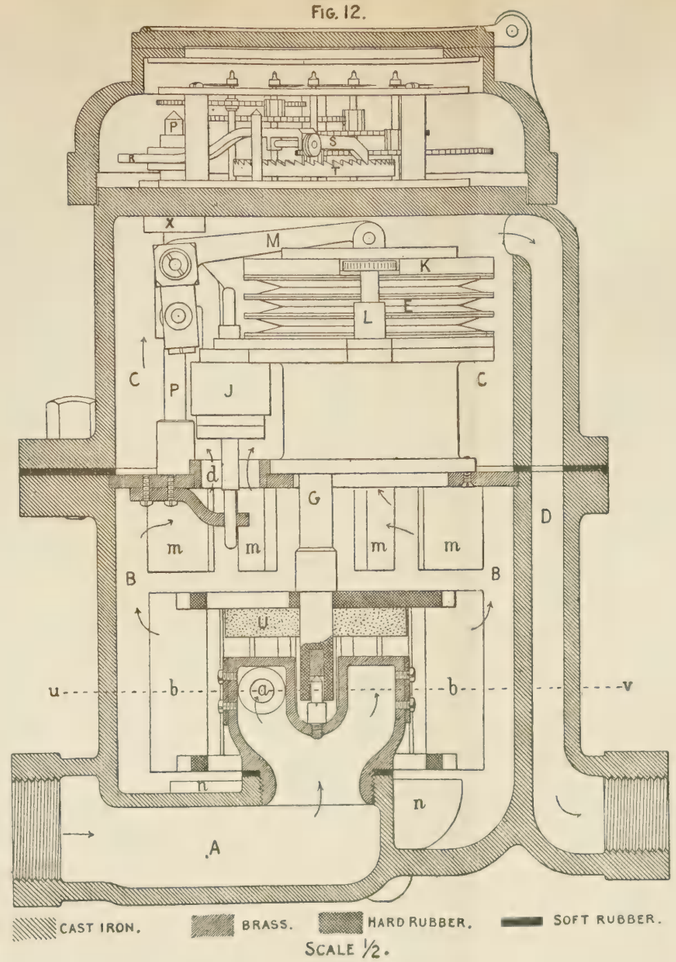


FIG. 16.

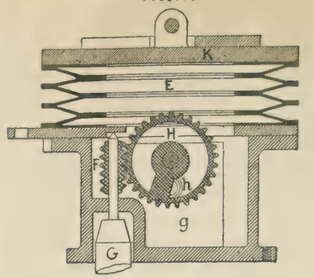


FIG. 17.

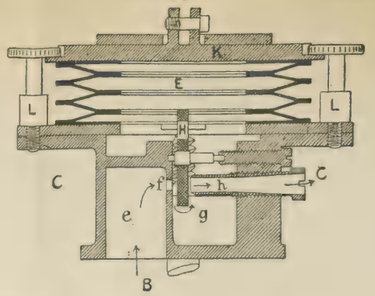


FIG. 15.

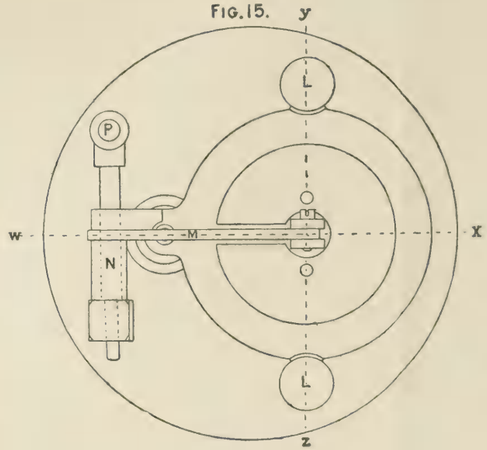


FIG. 18.

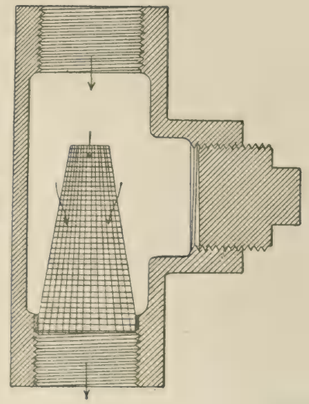


FIG. 14.

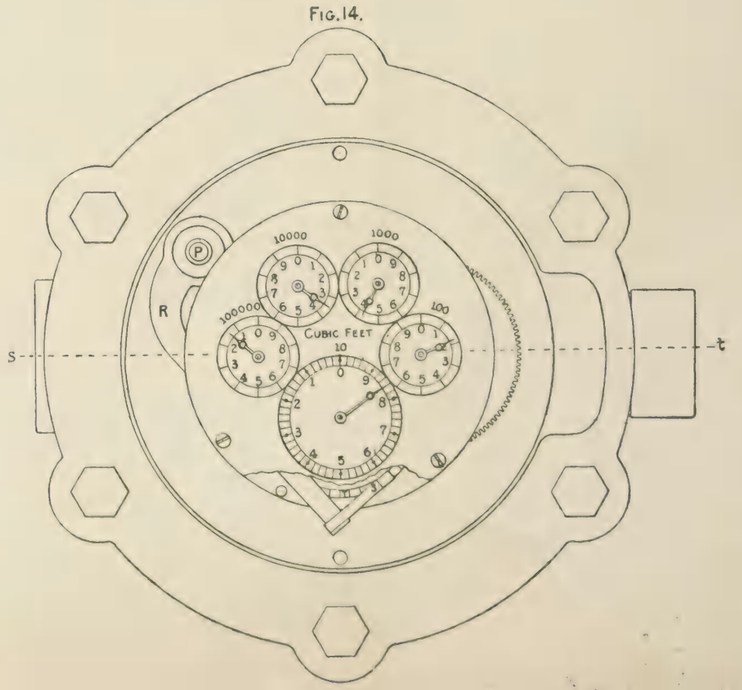
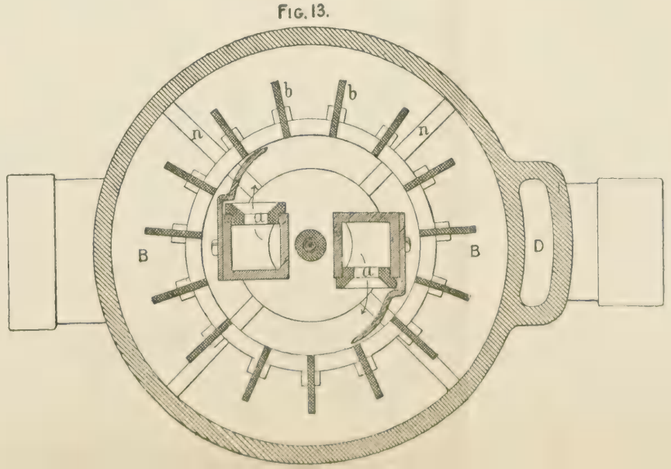


FIG. 13.



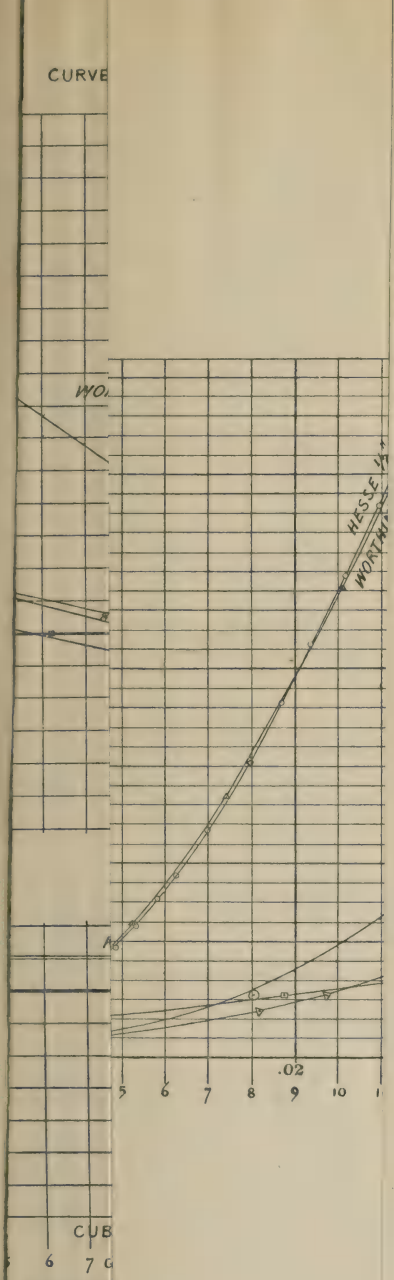

CURVE
WO
HASSE
WORTH
.02
5
6
7
8
9
10
CUB
6
7
9 GALLON

PLATE No. VII.

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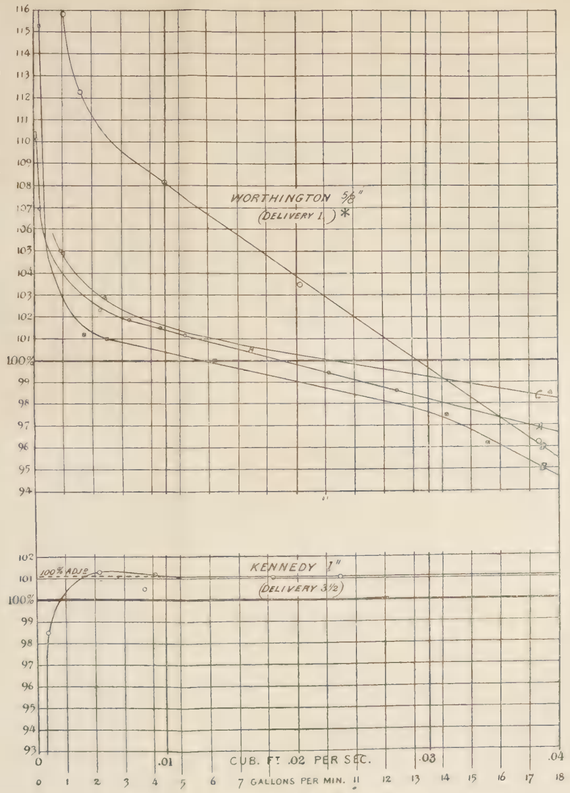
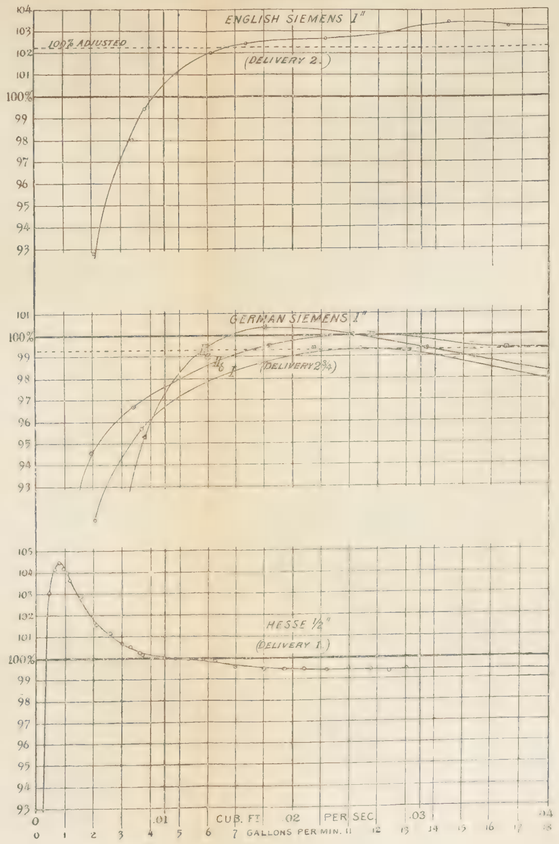
Browne on Water Meters.

CURVES OF REGISTRY

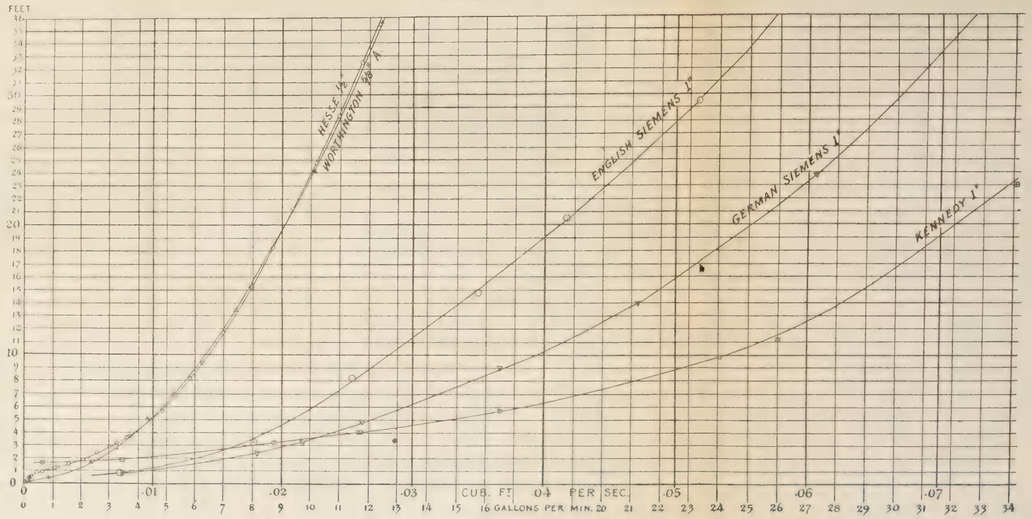


* UNIT OF DELIVERY 9 GALLONS PER MIN. WITH 20 FEET LOSS OF HEAD.

CURVES OF REGISTRY



CURVES OF HEAD LOST



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XVIII.

VOLUME II.—APRIL, 1885.

A TALK ABOUT EXPLOSIVES.

By WM. R. QUINAN, Mem. Tech. Soc.

Read April 3, 1885.

The use of gunpowder in Europe can be traced only to the middle or early part of the 14th century. It is not likely that the crude experiments of the German monk, Berthold Schwartz, had much influence in introducing it into European warfare. The better theory seems to be that a knowledge of it was obtained from the Saracens. The invention probably had its origin in central Asia, where saltpetre occurs as an efflorescence on the soil, and where the campfires of the prehistoric nomad must have frequently sputtered from the deflagration of the nitre in contact with the heated embers. The Chinese appropriated the discovery at a very early period, and fireworks were common in that country when Europe was peopled by primitive savages. There are records which seem to show that when Alexander invaded India in 327 B. C., he encountered tribes that used something equivalent to the modern rocket. In the invasion of China by Gengis Khan in A. D. 1219, similar fire machines were used. Wars and migrations of tribes disseminated a knowledge of gunpowder over Asia and northern Africa, and in the hands of the Saracens the art seems to have advanced to its use as a projectile agent.

We find the Moors using it in this way in Spain in 1312, and soon afterwards guns made their appearance upon the battlefields of Europe.

Whether this rough historical sketch be substantially correct or not, a knowledge of the composition of gunpowder and of its manufacture in a crude way, seems to have existed from time immemorial throughout the greater part of central and southern Asia. In this primitive method of manufacture, the incorporation of the ingredients is effected in a wooden mortar, the pestle being often worked by a treadle. This method is still in use in India among the hill tribes, and in Afghanistan, where the work is usually done by the women. The moist mass taken from the mortars, is grained by being rubbed through sieves of catgut. The grains dried in the sun, are used without further preparation. In Col. Anderson's account of the Bengal Powder Mills, he gives some tests of a superior Sekh Powder obtained from one of the native princes—2 ounces of which in the 8-inch mortar gave a range of 53 yards, while the Bengal powder gave 94. The appearance of the native powder is thus described—"grains mixed, round as if cast, not very hard, not much dust, color bluish-black." An analysis showed normal or nearly normal proportions of the ingredients. Its only inferiority seemed to lie in the fact that the saltpetre was not well refined.

The same author tells of a clever device for projecting a small shell without gun or mortar which one of the Sekh sirdars exhibited to a British officer. The sirdar excavated a hole in the ground at an angle of about 45°, slightly contracted at the bottom so as to form a small chamber. The chamber was next reinforced by driving in several tent pins till their heads were flush with the bottom. A piece of quick match being laid to the mouth of the hole, a small charge of powder was introduced, and then the shell placed in with fusee lighted. Upon lighting the quick match, the shell was projected about 300 yards and exploded in falling to the ground. The excavation was very little injured by firing two rounds.

This story reminds one of the giant mortars of the island of Malta, made by excavating holes in the solid rock; and also of the device in fortification called a *stone fougasse*, a sort of impro-

vised underground mortar for throwing a shower of small stones, which was once in fashion for the defense of strong places.

Requirements of Gunnery.—Gunpowder owes its efficiency as an explosive, to certain chemical relations existing between its ingredients, but a perfect incorporation of these ingredients is essential to the full development of its force. It is important to observe that the evolution of its gases, is the result of a veritable combustion, and is therefore progressive. In the high explosives, on the contrary, the decomposition is supposed to be propagated by a vibration throughout the mass, and is sensibly instantaneous. The fact that gunpowder gives off its gases at a certain rate is the most important element in its use as a projectile agent; indeed, it is this property which suits it to the hand of the artillerist. The velocity of combustion is the rate at which solid powder burns and is defined to be the space passed over by the burning surface in a second of time, the space being measured perpendicular to the surface. This velocity is affected by several circumstances. It increases with the purity, dryness, and thorough incorporation of the ingredients, and diminishes with the density. That is, other things being equal, a carefully made powder burns most rapidly, and a light powder burns more rapidly than a heavy one. In the explosion of a charge, there is another velocity to be considered—that of inflammation, or the spread of the flame from one grain to another. This must not be confounded with combustion—the burning of the grains from surface to centre. It has been found by experiment that good gunpowder burns at the rate of about one half inch per second, while the velocity of inflammation, though it varies greatly with circumstances, and is much reduced by the presence of dust, may be taken between 25 and 100 feet in the explosion of a charge of grained powder. We may therefore suppose for our present purpose that the grains are all ignited at the same instant. It is evident that the evolution of the gas of a charge can be regulated to some extent by employing grains of a certain size. The smaller the grain the sooner the charge is burnt, and the quicker the evolution of gas. With small or light projectiles, the gases may be developed suddenly, and small grain powders are admissible. In large guns where the projectile

has great weight, it becomes necessary to the safety of the gun, to develop the inertia of the shot slowly. Experiment has proved that the pressure on the bore of a gun is by no means equal at all points of the bore, but is greatest near the seat of the charge. The disproportion is the greater, the smaller the grains. The aim in heavy guns is to lighten the initial pressures and increase the subsequent ones, so as to bring about something like an equality. When a charge is lighted in the bore, experiments have proved that the pressure mounts almost instantly to a little below the maximum, then more slowly to the maximum, at which moment the shot has moved so far that the pressure of the gas, which is still increasing, is balanced by the increase of room left by the moving shot. From that moment the life of the gun is safe. It is evident that the conditions aimed at cannot be fulfilled by ordinary grains of powder, no matter how large, because from the relations between concentric spheres of equal thickness the amount of gas evolved in the first instants of burning will be too large, tending to excessive pressure, and that in the last instants will be too small, and will fail in accelerating the shot.

Gen. Rodman, of our Ordnance Department, was the first to clearly comprehend this difficulty, and to attempt a remedy. His solution was to compel the powder to burn on an increasing instead of a diminishing surface. He gave his powder the form of large cakes, perforated with numerous holes. His experiments with this powder showed a marked diminution of maximum pressure with increased effect on the projectile. Experiments since Rodman's death have failed to confirm his results. Accidents have occurred, possibly from the wedging of the broken cakes in the bore.

Lieutenant Totten, of the 4th Artillery, is the inventor of another method of meeting the difficulty. He calls his a "compensating powder." He proposes a spherical grain of gunpowder inclosing a small core of gun cotton. The projectile is started by the gunpowder, but is accelerated after passing the danger point by the quicker burning gun cotton. His patent covers other combinations as well, the general idea being to combine a slow and quick burning explosive, so as to make them operate at different periods in the explosion of the charge.

Composition and Manufacture.—In its best known form, gunpowder consists of potassium nitrate, sulphur, and charcoal. This composition is the one still used in military and sporting powders. In blasting powder the potash salt has been very generally superseded by sodium nitrate. For blasting purposes the latter is but little inferior to saltpetre, while its cost is much less. The slightly deliquescent nature of the soda salt has been counteracted by a high degree of glazing and the use of metallic cases for packing.

The tendency of late years in the manufacture of blasting powder, is to also lessen the cost, by doing away with the older elaborate methods of grinding and incorporating the ingredients. An intimate mixture is obtained by dissolving the nitrate in the smallest possible quantity of boiling water and stirring the other ingredients, previously ground and mixed, into the solution. To prevent the nitrate from crystallizing too coarsely, the mixture is vigorously stirred during the evaporation of the water. Sometimes the mixture is ground a short time in the wheel-mill, and sometimes granulated directly from the boiling vat by being rubbed while damp and cohesive through coarse sieves. In most mills it falls upon a wide canvas belt, which transports it to the drying house.

This powder is deficient in density and cohesion, and unless glazed, has poor keeping qualities. The incorporation is very imperfect, the crystals of nitrate being visible to the naked eye. It works fairly well as a blasting agent, though it is very slow in spite of its lightness.

Sometimes the grains are toughened, and the explosive qualities of the powder injured by the addition of a small percentage of sugar to the other ingredients. This method of manufacture is very old. It was used more or less in Europe during the seventeenth and eighteenth centuries. Nevertheless, with various minor modifications, it has been the subject of a half dozen United States patents.

On this Coast this method has been identified more or less with Mr. Orlando B Hardy, of Akron, Ohio, who took out a patent for a new blasting powder in 1879. The novelty consisted in adding to the ordinary ingredients salt, sugar and paraffine—

whereby he obtained a powder "fully equal in dynamic effect to 'Giant' or 'Hercules,'" and which had also the property of being "non-explosive in the open air."

Mr. Hardy established a mill at Vallejo, where he turned out at first probably the worst specimen of blasting powder which has ever been offered to the public. These works were blown up in 1882, after he had left them, but were rebuilt at Sobrante. They now turn out a very handsomely glazed powder called "Granite." Hardy was employed by the Vulcan Powder Company to build and take charge of works at Stege. The powder made here was a crude, unglazed product, and was largely used in contracts with the Southern and Central Pacific railroads, under the name of "Vulcan B. B." or "Bank Blasting." As its name implies, it was made specially for the hydraulic mines, in which it found some application. The works at Stege were blown up and rebuilt in 1882. In 1883 the powder was changed by adding a small proportion of nitro-glycerin, into a detonating explosive, under the name of "Ajax." This powder was largely used for a short time in a contract for extending beyond Redding the Oregon branch of the Central Pacific. The powder contract, so far as it concerned the Vulcan company, was ruptured suddenly by the transference of Mr. Hardy's allegiance to the Giant company. Upon the grounds of the latter, near Berkeley, works were erected similar to those at Stege. The only change of importance was the use of hot air instead of steam for the dry-house. These works have a capacity of 20 or 25,000 pounds of powder per day.

The "Ajax" powder was changed by substituting ordinary coal for charcoal, and took the name which it still keeps of "Judson Improved."

The most notable departure, perhaps, from the ordinary methods of manufacturing gunpowder, is that of Col. Bernhard Wiener, of the Russian Artillery. He takes the dry meal from the mixing tubs or barrels, and subjects it to the action of a press heated to about 250° Fahrenheit. This causes the sulphur to melt and pervade the mass. The product is a light but very firm powder. It is said to stand water well. The process is quicker and cheaper than the old, but little is known so far

of the general qualities of the powder. Col. Wiener took out his U. S. patent in March, 1874. Some specimens of his powder were sent for by the authorities of the Artillery School at Fort Monroe, but I have not heard whether any tests were made.

The situation of this Coast during the War of the Rebellion, when all the Eastern mills were working day and night upon government contracts, and the dearth of blasting powder for the hydraulic mines and railroads ran the price up some three or four times the normal, was a powerful incentive to inventors of rough-and-ready powders. Mr. Egbert Judson once told the writer of a venture of his at this time. He went off into the sand-hills of San Francisco and erected some shanties, from which, inside of a week, he was shipping powder to the mines. The carbonaceous element was principally sawdust, a part of the nitrate being replaced by potassium chlorate. To give a black color, sulphate of iron was added in small quantity. This formed an ink with the tannic acid in the sawdust. The powder was made by dissolving the nitrate and chlorate in hot water and stirring in the other ingredients. Mr. Judson says he made money until the better made Eastern article began to return to the market at lower prices, when he demolished his shanties and gave up the business.

Gunpowder Modifications.—The progress of the arts has introduced more or less extensively a great number of inventions intended to supersede gunpowder as a blasting agent. In the composition of these explosives, inventors have been guided very generally by the principle of the older explosive. Most of the attempts to invent something new have consisted in obvious modifications, made by substituting equivalent elements for those of gunpowder. Under the head of substitutes for charcoal, we find tannin, coal, peat, sawdust, bark, paraffine, starch, sugar, etc. All of these substances are deficient in chemical energy as compared with charcoal. The effect of using them with a nitrate as the oxidizing agent, notwithstanding the claims of the inventors, is to weaken the powder by making it slow and sluggish. For certain kinds of work these compositions may do very well, but for general purposes they are inferior to the old explosive.

Perhaps a judicious use might be made of them in some modified form of gunpowder for heavy guns.

Under the second head of oxidizing agents we find the nitrates, chlorates, etc. There appears to be a great choice of these substances, but when we examine the subject closely we find that the choice is very limited.

The following is a table of some of the nitrates, showing the percentage of oxygen, etc.:

Name.	Symbol.	Molecular Weight.	Percentage of Oxygen.	Percentage of Gaseous Constituents.	Remarks.
Urea Nitrate.....	$COH_5N_2(NO_3)$	123	52.0	100.	Stable—not deliquescent.
Ammonium Nitrate.	NH_4NO_3	80	60.0	100.	Deliquescent.
Magnesium Nitrate.	$Mg(NO_3)_2$	148	64.9	83.8	"
Calcium Nitrate...	$Ca(NO_3)_2$	164	58.5	75.6	"
Sodium Nitrate	$NaNO_3$	85	56.5	73.0	Hygroscopic.
Ferrous Nitrate ...	$Fe(NO_3)_2$	180	53.3	68.9	Unstable.
Potassium Nitrate..	KNO_3	101.1	47.5	61.3	Stable soluble.
Strontium Nitrate..	$Sr(NO_3)_2$	211.5	45.4	58.6	Sparingly "
Barium Nitrate.. ..	$Ba(NO_3)_2$	261	36.8	47.5	" "
Lead Nitrate	$Pb(NO_3)_2$	331	29.0	37.5	" "

This table shows the nitrates arranged according to the percentage of gaseous constituents. The percentage of oxygen is also shown in one of the columns. All of this oxygen is not available however for outside combination. For instance, though the urea nitrate is a genuine nitrate, it is not an oxidizing agent at all, as every atom of oxygen in decomposition is required to oxidize the other constituents, and even then there is not enough. The ammonium nitrate is an oxidizing agent, but a feeble one, as it contains only one atom of oxygen for outside combination. The other nitrates are genuine oxidizing agents, but most of them are unfit for powder. The nitrates of lime and magnesia are so deliquescent that they are worthless for explosive purposes. The ferrous nitrate is unstable—that is, liable to spontaneous decomposition. This leaves five available ones—the nitrates of soda,

potash, strontia, baryta, and lead. We are already familiar with the first two. The others are feeble, partly from deficiency of oxygen and partly for another reason. Judging from this table the sodium nitrate should be superior to potassium nitrate, but the latter is known to make a stronger gunpowder in spite of the greater amount of oxygen carried by its rival. When a gunpowder is fired, various solids are formed, which are salts of potassium, or sodium, or barium, etc., accordingly as the nitrate used in the powder is a potassium, sodium or barium nitrate. The formation of these salts develops different amounts of heat, depending upon the nature of the base. As the heat is one of the elements of strength, we see why the gas-forming capacity of the nitrate, taken alone, does not measure the strength of the corresponding gunpowder.

In addition to the nitrates, there are a number of other substances which have been called upon by inventors to play the part of oxidizing agents. The following is a list of certain substances:

Name.	Symbol.	Molecular Weight.	Percentage of Oxygen.	Remarks.
Hydrogen Peroxide	H_2O_2	34.	94.0	Unstable.
Manganese Dioxide.....	MnO_2	87.	37.0	
Zinc Oxide.....	ZnO	81.	19.8	
Lead Peroxide.....	PbO_2	239.	13.4	
Mercury Oxide.....	HgO	216.	7.4	
Potassium Chlorate	$KClO_3$	122.6	39.1	
Potassium Perchlorate...	$KClO_4$	138.6	46.2	Very costly.
Potassium Permanganate	$K_2Mn_2O_5$	268.2	29.8	Unstable.
Potassium Bichromate....	$K_2Cr_2O_7$	294.6	38.0	

Hydrogen peroxide, or oxygenated water as it is called sometimes, is a very interesting substance and a powerful oxidizing agent; but it is too unstable for powder. Moreover, it is a liquid which so far has only been prepared as a solution in water. It contains, as shown by the table, 94 per cent. of oxygen, but only half of this is available for outside combination. Certain of the

metallic oxides are given in the table, because they have been proposed as powder ingredients by different inventors. A glance at the table shows that most of them are of no account. In the higher oxides, as a rule, only a part of the oxygen is readily separable. Some of the lower oxides attract carbonic acid from the air, and are spontaneously converted into carbonates. The manganates and permanganates are powerful agents, but are too unstable, being decomposed by contact with organic matter.

Potassium bichromate has been used by various inventors. It is not very energetic, and is commonly used with other and stronger agents.

Potassium perchlorate is a very interesting substance. It is exceedingly energetic, and at the same time stable. It has many properties to recommend it to inventors, but at present its preparation is too costly to bring it into the field.

Potassium chlorate is the only substance in this table which has come into general use as a powder material. By comparing the table with that of the nitrates, it will be seen that the chlorate furnishes less oxygen than either the nitrate of soda or potash. It is, however, a much more energetic agent than the nitrates. This can be explained in this way. It gives up its oxygen more readily, because it is susceptible of an independent decomposition with *evolution* of heat, thus:

$$KClO_3 = KCl + O_3$$

If we try the nitrate in the same way, we find that the decomposition takes place in opposition to the affinities of the K and O with an *absorption* of heat, thus:

$$KNO_3 = K + N + O_3$$

Practically we can get only a partial decomposition unless we raise it to a very high temperature.

The introduction of potassium chlorate into the arts was attended with so many accidents that it merits an extended notice. It was first made known to the world in 1785 by the celebrated French chemist, Berthollet, who named it "oxygenized muriate of potash," which was afterwards shortened to oxymuriate of potash. When, in 1809, Sir Humphrey Davy proved

that chlorine contained no oxygen, the name was changed to chlorate of potash. The older chemists indulged in extravagant flights of imagination in describing the qualities of the new compound. Fourcroy, in his chemistry, says "it appears to include the elements of thunder in its particles," and that "Nature seems to have concentrated all her powers of detonation, fulmination and inflammation in this terrible compound." At the present day, this language seems very much strained in view of the later discoveries of the fulminates, nitro-glycerin, and other high explosives. However, the lives of the two first workmen employed by Berthollet in manufacturing gunpowder from chlorate of potash were sacrificed in the experiment. The trituration of the chlorate with charcoal and sulphur caused a violent explosion, which killed the men and destroyed the building. This was in 1788. The incorporation of these ingredients is a very dangerous operation, but it has been successfully accomplished since, by more careful experimenters, who managed it by keeping the composition wet. Several French chemists prepared such powders, and found by experiment that they had about twice the strength of ordinary gunpowder. M. Cossigny made the mixture by dissolving the chlorate in water and stirring in the other ingredients. His proportions were 75 chlorate, 12½ sulphur, and 12½ charcoal. He also experimented with mixtures of chlorate and nitrate in different proportions. Several attempts were made under Bonaparte to make practical use of these powders, and it is said that in one of his campaigns they were actually used. It was soon found that the injury to the gun, both from the violent nature of the explosive and corrosive action on the metal, more than counterbalanced the superiority in strength.

There exists among mining men a great prejudice against potassium chlorate mixtures, and this is not to be wondered at when we consider the great number of accidents which have resulted from handling it. Mixed with organic matter of almost any kind, and suddenly heated or violently struck, it will yield an explosion which is local or complete, depending upon the nature of the mixture. In contact with certain substances, it is very sensitive to friction. Grinding it has led to numerous accidents in past times, owing to organic impurities in it, or allowed

to get into it, in the mill. It is used in the arts as a source of oxygen gas, for which purpose it is mixed with manganese dioxide and heated in a retort. Adulteration of the oxide with coal, by ignorant or unscrupulous dealers, gave rise to numerous explosions. Mixed with sulphur or certain sulphides, explosion is readily caused by a blow or friction, but it is usually local unless in the presence of charcoal or carbonaceous matter, when it is apt to be violent. Mixed with sugar or the cyanides, or some of the nitro-substitution compounds, it is inflamed by a drop of sulphuric acid. The latter acid produces by its action on the chlorate alone an explosive gas. These facts and the widely varying conditions which seemed to cause accidents with it, united in giving chlorate of potash a name for instability which it does not deserve. It is simply a substance with a great range of chemical susceptibilities, which must be carefully studied by the inventor who attempts to use it in compounding powders. Undoubtedly many mixtures have been put upon the market which were intrinsically dangerous, but powders can be made from it, by consulting its chemical relations, which are reasonably safe. In a state of great purity, it is now an article of an extensive commerce. No accidents now-a-days happen with it, which can be alleged to be "spontaneous" or "atmospheric."

Chemistry has disclosed a great many substances which may be used in compounding explosives. We have already mentioned some capable of playing the part of oxidizing agents. Among the most interesting of the opposite nature that is capable of replacing charcoal, is carbon bisulphide—CS_2. This is a transparent liquid, quite volatile, and having in its ordinary state of purity a repulsive odor. Mixed with potassium chlorate, it is said to form a powerful detonating explosive, but which has no practical value on account of the volatile character of one of the ingredients. When the bi-sulphide is heated with zinc and sulphuric acid, it takes up two atoms of hydrogen, forming a very interesting white solid substance having the formula CH_2S. I think it likely that this would be found an energetic agent in explosive mixtures. No experiments have been made with it.

Knowing the general principles of chemistry it is easy to

theorize on the effects of a new agent. To illustrate the course of reasoning by which an inventor arrives at a new combination, we will begin with one of the simplest reactions with potassium chlorate, viz:

$$3C+2KClO_3=3CO_2+2KCl.$$

Nitrogen is a substance having feeble affinities for other elements. Its presence is almost a characteristic of explosives. We can improve the reaction therefore in this way:

$$3CN+2KClO_3=3CO_2+3N+2KCl.$$

But CN is cyanogen, a gas. We try again. Hydrogen combines with oxygen with great avidity, producing great heat. Our equation becomes:

$$6HCN+5KClO_3=6CO_2+3H_2O+5KCl+6N.$$

Here (HCN) we have another gas, a virulent poison, the concentrated aqueous solution of which is the ordinary prussic acid. But we can substitute another element for hydrogen, such as potassium, giving us potassium cyanide. This makes with the chlorate, an efficient explosive, but the cyanide is deliquescent, and the powder soon spoils. Most of the simple cyanides have the same defect—the soluble ones are poisonous. The cheapest and most stable of these compounds is the double cyanide of potassium and iron; or, as it is usually called, the ferro-cyanide or yellow prussiate of potash. This is not poisonous, and is not deliquescent. The reaction may be represented as follows:

$$K_4FeC_6N_6+\tfrac{14}{3}KClO_3=2K_2CO_3+4CO_2+6N+Fe+\tfrac{14}{3}KCl.$$

This composition is known in the arts as "German" or "white" gunpowder. It is much stronger than ordinary powder but too costly to be very serviceable in mining. To cheapen it and to make it less sensitive to friction, sawdust is sometimes mixed with it. In some compositions sugar is used instead of sawdust. It can be exploded by a drop of sulphuric acid. A blasting powder made by mixing potassium nitrate, charcoal and the ferrocyanide, called haloxylin, has found some application in Germany.

Explosion.—Explosion is a term used in ordinary conversation to designate phenomena which are totally dissimilar except in outward and visible manifestation. Thus water is said to explode when by sudden conversion into steam it bursts a boiler. Technically, explosion is a chemical reaction which forms suddenly a body of heated gas. Explosions take various forms. The body which explodes may be a mixture of gases, as hydrogen and oxygen, which unite with great energy under certain conditions to form the vapor of water. In this case, the only expansion is from the great heat produced, as under the same temperature and pressure the vapor formed would occupy only two-thirds of the volume of the mixed constituents before explosion. Usually the exploding body is a liquid or solid which is transformed wholly or partly into gas. The gases produced by explosion are generally compound gases formed by the union of certain elements contained in the exploding body; but sometimes the case is reversed and the gases are simple elements formed by the disunion of two or more elements which were united in the explosive. This case is illustrated by the explosion of nitrogen chloride, which consists in the sudden dissociation of its elements. In gunpowder also the nitrogen of the nitrate is set free in the explosion. The gases most characteristic of explosion are the oxides of carbon, the vapor of water and free nitrogen.

Construction of Explosives.—Generally speaking the structure of an explosive exhibits two elements: oxygen on the one hand and some substance or substances having a strong affinity for oxygen on the other. In regard to composition, the most general division is into two classes: 1st, Explosive mixtures. 2d, Explosive compounds. Explosive mixtures are built up by assembling an oxidizing agent with some substance or substances having a strong affinity for oxygen and capable of forming gas by union with it. In an explosive mixture there is no union between the elements beyond an intimate mechanical one. In practice the products of explosion are both solids and gases, though it is possible to make explosive mixtures having only gaseous products.

An explosive compound is a true chemical compound, which is an explosive within itself. Nitro-glycerin, mercury fulminate and gun-cotton, are examples. The products of explosion are generally gaseous, though there are numerous exceptions as in the case of the metallic fulminates, picrates, etc. An explosive compound may be used in mixture with substances which are inexplosive in themselves or may be mixed with other explosives. To such mixtures the term explosive compounds is very generally applied though not with strictness. An explosive mixture, however, is one in which no substance enters which is capable of explosion in itself.

Explosives can be divided practically into the same two classes on another basis. Those which explode by combustion or burning, belong to the first class. Those which can be exploded by detonation, to the second class. The first class includes explosive mixtures or fire-explosives—the second class, explosive compounds and their derivatives, or detonating explosives. In the first class, explosion is caused by a progressive burning of the mass—in the second by an exploding impulse which is transmitted almost instantaneously throughout the mass. The distinction between the two forms of explosion is one of time. When we compare typical examples of the two classes—as gunpowder and nitro-glycerin, there appears to be a radical difference, but when we examine a variety of explosives, we find the two graduating by insensible degrees into each other so that no exact line can be drawn between them. However, most of the explosives known to the arts can be placed with confidence in one or the other class.

Detonating Explosives.—Of the detonating explosives in practical use, the fulminates were the first discovered—this was about the beginning of the present century. At first it was believed that they would play an important part in gunnery, but this notion was dispelled when their nature came to be fully understood. Though the amount of gas furnished by them is small, they explode with great violence. In rapidity of decomposition they probably exceed nitro-glycerin. This gives a peculiar local character to the explosion. Berthelot holds that the pres-

sure generated by the fulminate of mercury on bodies closely enclosing it, is greater than that of any other known explosive. He estimates it at 40,000 kilogrammes per square centimeter, or over 500,000 pounds on the square inch. To illustrate the local character of the explosion—it is said that in the cap factories a man has been killed by a shock which left another almost at his elbow unharmed. The mercury salt is the only one used in the arts. Pure or mixed with either potassium chlorate or nitrate, it is used in making gun caps and primers, and also the caps or detonators employed to explode nitro-glycerin, gun-cotton and other high explosives. For the latter purpose a small percentage of gun-cotton is sometimes mixed with it. It is the best detonating agent we have for the high explosives.

Nitro-Substitution Compounds.—About 1846 a new list of high explosives was given to the world in the discovery of the nitro-substitution compounds, gun-cotton, nitro-sugar, nitro-glycerin, etc. These compounds are formed by the action of strong nitric acid on the organic substances, cotton, sugar, glycerin, etc. The number of nitro-substitution compounds now known to chemists is very great. A large proportion of them are explosive. The reaction by which these substances are formed is a curious and interesting one. Nitric Acid has the formula HNO_3. In the reaction it is divided into HO and NO_2. The radical NO_2 is called nitryl. It replaces H in the organic substance acted upon—one molecule of NO_2 taking the place of one atom of H. The atom of H displaced unites with the other part of the nitric acid, that is the HO, to form water H_2O. Many substances are capable of forming several distinct nitro-substitution compounds depending upon the number of hydrogen atoms replaced, or as it is commonly called, the degree of nitration.

Gun-Cotton.—Gun-cotton is the most highly nitrated form of nitro-cellulose. Nitro-cellulose can be readily made from a great variety of substances, such as cotton, linen, jute, vegetable pith, woody fibre, saw dust, etc. Special precautions are required however to make gun-cotton proper, or tri-nitro-cellulose, and

cotton is the best material to operate upon. The lower forms of nitro-cellulose are readily distinguished from the higher by being soluble in ether. The solution of these compounds in a mixture of ether and alcohol is familiar to us all under the name of collodion. It is a well known agent in both surgery and photography.

Camphor is another solvent for the lower forms of nitro-cellulose. This discovery is very interesting as being applied in the manufacture of a substance of great utility and importance in the arts. In the preparation of this, the nitro-cellulose is ground to a fine dust by special machinery and intimately mixed with camphor which has also been reduced to fine particles. Certain inert matters, to give body or color, are also added. When submitted to pressure and a certain degree of heat the nitro-cellulose is dissolved by the camphor and loses all trace of its original structure. The resulting substance is celluloid, or artificial ivory—one of the happiest hits of American inventive genius.

The explosiveness of nitro-cellulose depends entirely on the degree of nitration. The lower forms are almost non-explosive, being deficient in the necessary oxygen. The intermediate forms have been used by various inventors in making explosive mixtures, such as Reeve's gun-felt or Schultze wood-powder. The latter is made by nitrating small cubes of wood and then soaking them in a solution of nitre. This powder was used somewhat on the continent of Europe. In this country the most persistent experimenter in this line is Carl Dittmar. It seems to have been the ambition of his life to make a sporting powder on this principle. He has tried various expedients. His last powder is made—(or rather was made—the writer has heard nothing of it for several years) by punching tiny discs out of wood-pulp card-board and nitrating these, and then soaking them in a solution of nitre. He has taken out various patents on the subject. One is for parchmenting the discs with sulphuric acid. Those of you who are sportsmen may have tried his powder. The writer has heard of several accidents with it, in which sportsmen have had their guns destroyed and have come near losing their lives. It

is possible that these accidents can be explained by the tendency of nitro-cellulose to detonate under strong confinement.

There is a sporting powder of this kind now in the San Francisco market, called "wood-powder." It seems to be a nitro-cellulose, made from very fine wood-fibre, incorporated with about twelve per cent of nitre and roughly granulated through seives. It is very light. The color is a brownish yellow. When burned in the open air it leaves a residue of charred matter. In the gun it is said to be very clean. The strength is about equal to gunpowder, volume for volume. No accidents with it have been heard of. It probably owes its safety to the low grade of the nitro-cellulose.

Gun-cotton had the advantage of most of the earlier discovered nitro-substitution compounds, in being susceptible to two different forms of explosion—by ordinary combustion and by detonation. Nothing whatever was known of the latter method of exploding it, but its property of exploding by combustion placed it at once within the experience of the many persons familiar with the use of gunpowder. In the open air a small quantity of it will burn with a quiet flash. Confined in the bore of a gun, it undergoes a combustion which is much more rapid than gunpowder, but like gunpowder the burning may be regulated to a certain extent. It is made slower by spinning the fibre into yarns. Austria made an extensive trial of it for artillery purposes, but finally gave it up for its older rival, gunpowder.

Its history as a blasting agent dates from the use of the detonating cap, which developed energies in it which had never been dreamed of. It has been used extensively in the torpedo service of England and various continental nations. Professor Abel of England, has devoted much time to the improvement of its manufacture. For storage in the arsenals and on shipboard, it is kept wet, in which condition it can only be exploded by a heavy primer of the dry gun cotton. Professor Abel introduced into its manufacture the process of pulping it after nitration, which enables it to be thoroughly washed and purified from the adhering free acids. This pulp is afterwards compressed into hard discs, to give it the density and concentration of power necessary in high explosives.

The only attempt in this country to bring gun cotton into competition with nitro-glycerin for blasting purposes, was made on this Coast a few of years ago, in the establishment of the Tonite Powder Company. Tonite is an English invention. It is composed of pulped gun cotton and barium nitrate, thoroughly incorporated and compressed into a solid stick or cartridge. It is very insensitive to shocks which will readily explode nitro-glycerin powders. Compared with nitro-glycerin preparations, it is deficient in strength, while it is more costly. So far it has not proved a success in this country.

Gun-cotton presents such decided advantages as a ballistic agent, that many attempts have been made to use it in small arms. These advantages are the presence of very little smoke, and but a trifling residue of solid matter to foul the gun. One objection to it is that it attracts and obstinately retains moisture. Its sensitiveness to confinement makes it a dangerous agent. When exactly the same conditions are preserved, its effects are probably more certain and invariable than those of gunpowder. The writer has seen but one gun which used a gun-cotton cartridge successfully. This was a small but very strong sporting rifle. The cartridge was a loose tuft of gun-cotton, tied longitudinally along a piece of wood about the size of a parlor match. The bullet was prevented from compressing the cartridge by resting against the end of the stick when pushed home.

The most noted attempt to prepare gun-cotton like ordinary powder, is that of Punshon, who mixed the pulped material with sugar. This invention received considerable attention in England eight or ten years ago, but little has been heard of it lately. It probably failed because the hygroscopic effects of the gun-cotton were aggravated by the sugar.

In the *Engineering Magazine* in 1881, there was a notice of a new English sporting powder made from gun-cotton and some material which was kept secret. The powder proved very satisfactory in a series of experiments designed by the inventor, Mr. W. T. Reid. This powder has gained some reputation since, but the writer does not know to what extent it has come into practical use. It seems to be simply a mixture of finely ground gun-cotton and nitrates. The conceded advantages of gun-cotton as to absence of residue and smoke, etc., are claimed for it.

Lack of space compels me to pass over a number of interesting explosives, such as nitro-mannite, nitro-glucose, nitro-sugar, tri-nitro-phenol or picric acid and its salts, the picrates, etc.

Nitro-Glycerin.—Nitro-glycerin is the most powerful explosive known to the arts. It was discovered by Sobrero in 1846, and was first practically applied as a blasting agent by Alfred Nobel, a Swedish mining engineer. He began his experiments about 1863, but it was not until he discovered that the fulminate cap could be used to explode it, that it became of any value. He established factories for its manufacture in 1866-67, and started an extensive trade in the liquid, which was shipped to all parts of the world. In this country, in 1873 and 1874, the liquid was used quite extensively in the Eastern States. The many accidents attending its transportation and use, led to its abandonment in favor of its powder modifications.

Nitro-Glycerin Powders.—The first and most celebrated of these modifications was Dynamite, or Nobel's Safety Powder, which consisted of a mixture of nitro-glycerin and kieselguhr, a porous infusorial earth, found in Hanover. The principle of dynamite is simple. The absorbent is inert—it adds nothing to the qualities of the powder but safety. By reducing the liquid to a compressible solid, it makes it insensitive to shocks which in the liquid or incompressible form would almost certainly explode it.

Nitro-glycerin powders may be divided into dynamites proper, or powders in which the absorbent is inert, and powders in which the absorbent contributes to the explosive effect. The simplest case of the latter is a mixture of nitro-glycerin with mealed gunpowder. This powder made its appearance very soon after the introduction of dynamite. So little importance was attached to it that the invention was not even patented, and yet it marked a great advance in powder making. The principle of safety is involved in this powder as well as in dynamite proper, while the power developed is much greater than that due to the nitro-glycerin alone, and considerably greater than the sum of the forces of the two ingredients fired separately. In other words the gunpowder is detonated by the nitro-glycerin. It has been shown

by certain French experimenters that the force developed by gunpowder when detonated is a fraction over four times its ordinary power. It is easy to understand this, if we reflect that the nitro-glycerin is exploded in the mixture with the same or perhaps greater facility than in ordinary dynamite, and that it develops an enormous heat—several thousand degrees centigrade—to which heat the gunpowder is instantaneously subjected. Its chemical energies are thrown into extraordinary activity throughout its mass, and its conversion into gas is no longer the result of a progressive combustion in which the chemical reactions rapidly follow each other, but by virtue of a single reaction induced simultaneously in all its particles. Theoretically, the heat and gas developed by the powder is the same as by ordinary firing, but the gases are evolved in a much shorter space of time, and the explosive effect is greatly increased.

This particular powder was followed by others in which the principle was extended to mixtures having the nature of gunpowder, but composed of different ingredients. On this Coast, at the present time, the favorite absorbent for nitro-glycerin is a mixture of sodium nitrate and wood fibre or wood pulp, as it is called. For ordinary gunpowder, wood fibre is a very poor substitute for charcoal. The empirical formula for cellulose, which wood fibre closely approaches in composition is $C_6H_{10}O_5$. We can make a theoretical gunpowder from this by mixing it with a nitrate thus:

$$\tfrac{5}{6}\,C_6H_{10}O_5 + 4\,NaNO_3 = 3\,CO_2 + 2\,Na_2CO_3 + 2\,N^2 + \tfrac{25}{6}\,H_2O$$

But practically this powder will not explode unless strongly confined, and even then its explosion is very feeble compared with gunpowder. When, however, the above mixture is detonated by nitro-glycerin, something like the above reaction takes place, and even more force is realized than from the detonation of gunpowder. We have seen that in gunpowder, potassium nitrate is a better ingredient than sodium nitrate, notwithstanding the greater percentage of oxygen furnished by the latter. In mixture with nitro-glycerin the case is reversed. The heat of the nitro-glycerin more than supplies the quickness naturally deficient in the soda salt.

The writer would say something about another very interesting explosive—Nobel's Blasting Gelatine, but in doing so he would be trenching upon the preserves of another member of this Society, who has made it the subject of special study, and has identified himself with its manufacture in two continents.

Chemistry of Explosion.—The great masters of chemistry have only recently turned their attention specially to explosives, but already some light has been thrown on the subject. We can dimly discern the germs of a theory which may, in the near future, be made to comprehend all the phenomena of explosion.

The energy of explosion resolves itself into the energy of chemical action or affinity, and one of the most careful authorities has said, when we talk of this, "we are venturing into a region which belongs entirely to conjecture, and is, at least at present, altogether beyond the reach of observation." We know, however, that this affinity is elective, and that it changes with temperature, pressure, and other conditions. The source of all chemical energy is in the uncombined, or rather the unsaturated atom. Like the stone carried to the house-top, it has potential energy. Moreover, to continue the simile, we can by chemical processes carry the atom to the very edge of the precipice and yet retain it from falling. When the stone falls under the action of gravity, or the atom unites with another under the action of the mysterious agency we call chemical affinity, its energy is converted into heat, work, or some other manifestation of force. Its energy has disappeared, and to restore its potency, requires the expenditure of the same work (or its equivalent) as developed by its fall. It would seem from this that the heat evolved in the formation of any chemical compound is a measure of its stability, since the same amount of energy must be expended in order to decompose it, and conversely that the same amount of heat or work, if applied, must necessarily decompose it. This speculative reasoning has received something like confirmation from the more recent discoveries in chemistry. It is known that when oxygen and hydrogen unite to form water, an enormous heat is evolved, in fact the greatest amount of heat known to be produced by chemical action for given weights of reagents. But it is

also known that the very stable compound, water, is decomposed into its original elements when subjected to a very great heat.

The great exponents of Thermo-Chemistry have recently divided all substances into two classes, *exotherms*, or those which evolve heat during formation and *endotherms*, or those which absorb heat. Heat of formation of a body is the heat involved in the chemical reaction which produces the body. Exotherms have a plus heat of formation, endotherms have a minus. The latter are comparatively rare, and other things being equal are the most unstable. The most noted example among explosives is nitrogen chloride, which absorbs a great amount of heat in its formation, which is again reproduced in its explosion. In a general sense the heat of formation of a substance is a measure of its stability, but one must not conclude from this that endotherms are necessarily unstable. Every reaction implies either a chemical decomposition or change of physical condition, and the heat of formation is the algebraic sum of the heats involved, which may be plus or minus as the heat of combination is greater or less than that of decomposition. Prof. Cooke thinks that the case of nitrogen chloride can be explained in this way. The reaction for its explosion is as follows:

$$2NCl_3 = NN + 3ClCl.$$

The heat produced is by the union of the nitrogen and chlorine atoms into molecules of each gas—and this heat exceeds that prodnced by the union of the different atoms into nitrogen chloride by 38,100 units of heat which is the number assigned for its heat of formation. When the explosive is formed heat is produced but it is masked by the greater heat lost by dividing the nitrogen and chlorine molecules into atoms.

The New Chemistry.—Our study of explosives has been greatly facilitated by the New Chemistry. The chemical equation is now a handy instrument in the hands of the investigator. It tells him at a glance some of the most important properties of an explosive. To make this clear, it will be well to recapitulate a few of the fundamental principles of the New Chemistry. The corner-stone of the structure is Avogadro's law, that equal volumes of all gases under like conditions of temperature and pressure contain the same number of molecules. These mole-

cules are real magnitudes, having both size and weight. They can be best conceived as very minute masses of matter occupying portions of space which are very small compared with the average spaces separating them. The molecules of one gas are small and light, and the molecules of another relatively large and heavy, but the number in a given volume under like conditions of temperature and pressure is the same. From this it follows that the relative weight of the molecule of any particular gas will also stand for the relative weight of the volume. The number of molecules in a given volume has been approximately calculated. One cubic inch of any and every gas contains at the standard temperature and pressure, viz: 0° centigrade and 76 centimeters of mercury—10^{23} molecules. It is well to remember that the law refers to molecules and not to atoms. A molecule of a compound gas, as HCl, CO_2, NO, is easy to conceive. HCl is a molecule which contains one atom of H and one of Cl, CO_2 is a molecule which contains one atom of C and two atoms of O. But when we take an elementary gas, as H or O, what does a molecule mean? The molecule then contains two atoms, as H_2, O_2, N_2, Cl_2, etc. Now we are all familiar more or less with the relative weights of the atoms, H=1, O=16, N=14, C=12, S=32, etc. The weights of the gas molecules will therefore be the double of these numbers H_2=2, O_2=32, N_2=28, etc. Let us adopt as the unit of volume a litre of hydrogen taken at the standard temperature and pressure, 0^0 and 76 centimeters. It follows from the law, since this volume will contain the same number of molecules of all the gases, that the relative weights of this volume of hydrogen will be 2, of oxygen 32, nitrogen 28, etc. If we take a compound gas, as HCl, it will be 36.5, CO_2 will be 44, etc. In other words the same numbers which express the relative weights of the molecules, will express the relative weights of equal volumes. The symbols for the elements stand for several things. Thus H stands for one atom of hydrogen or 1 gramme, or 1 pound of hydrogen and also for 1 volume of hydrogen; O stands for one atom of oxygen or 16 grammes, or 16 pounds of oxygen or 1 volume of oxygen; CO_2 stands for one molecule of carbon dioxide or 44 grammes of car-

bon dioxide, or two volumes of carbon dioxide. For convenience the weight of a litre of hydrogen at standard temperature and pressure is called a crith and is equal to .09 gramme, very nearly. Taking this as a unit, the relative weights of equal volumes of the elementary gases will be represented by their atomic weights, the relative weights of equal volumes of compound gases by one-half of their molecular weights. The beauty of the theory is brought out by simply constructing our formulas in molecules. Then each gas molecule will represent two volumes of the gas taken at the standard temperature and pressure. Thus the explosion of nitro-glycerin can be represented thus:

$$\begin{array}{ccccccccc} C_3H_5N_3O_9 & = & 3CO_2 & + & 2\tfrac{1}{2}H_2O & + & 3N & + & \tfrac{1}{2}O \\ 227 & & 132 & & 45 & & 42 & & 8 \\ & & 45 & & & & & & \\ & & 42 & & & & & & \\ & & 8 & & & & & & \\ \hline & & 227 & & & & & & \end{array}$$

If we change the second member so as to read so many molecules all through, it will read thus:

$$\begin{array}{ccccccccc} & & 6 & & 5 & & 3 & & \tfrac{1}{2} \\ C_3H_5N_3O_9 & = & 3CO_2 & + & 2\tfrac{1}{2}H_2O & + & 1\tfrac{1}{2}N_2 & + & \tfrac{1}{4}O_2 \\ 227 & & 132 & & 45 & & 42 & & 8 \end{array}$$

In which we have written the volumes of gas above and the weights below the symbols. If we now take the molecular weights in criths, we see that 227 criths (about 20 grammes of nitro-glycerin) will produce 6 litres of carbon dioxide, 5 litres of water vapor, 3 of nitrogen and $\frac{1}{2}$ litre of oxygen gas, taken at the standard temperature and pressure, $14\frac{1}{2}$ litres of gas in all. We also have the weight of each gas expressed in criths.

The reaction in the case of gunpowder, as usually understood, may be written thus:

$$\begin{array}{ccccccccccc} & & & & & & & & 6 & & 2 \\ 2KNO_3 & + & 3C & + & S & = & K_2S & + & 3CO_2 & + & 1N^2 \\ 202 & & 36 & & 32 & & 110 & & 132 & & 28 \\ 36 & & & & & & 132 & & & & \\ 32 & & & & & & 28 & & & & \\ \hline 270 & & & & & & \overline{270} & & & & \end{array}$$

That is, 270 criths (about 24 grammes) of potassium nitrate gunpowder will produce 8 litres of gas taken at the standard temperature and pressure. Reducing the quantity to 227 criths to compare it with nitro-glycerin we have 6.7 volumes of gas.

If we take a sodium nitrate powder the reaction will be—

$$\begin{array}{ccccccccc} & & & & & & 6 & & 2 \\ 2NaNO_3 & + & 3C & + & S & = & Na_2S & + & 3CO_2 + 1N^2 \\ 170 & & 36 & & 32 & & 78 & & 132 \quad 28 \\ 36 & & & & & & 132 & & \\ 32 & & & & & & 28 & & \\ \hline 238 & & & & & & 238 & & \end{array}$$

That is 238 criths of the powder ($21\frac{1}{2}$ grammes) will give 8 litres of gas. Reducing as before, we find that 227 criths would produce 7.6 volumes of gas.

Heat of Explosion.—To judge properly the power of an explosive it is necessary to consider something besides the amount of gas. By this term "amount of gas," we mean the volume of gas reduced to the standard temperature and pressure. The gas has its tension enormously increased by the intense heat produced.

The heat of chemical action has been the subject of much study by eminent chemists of late years. The heat involved in a given chemical reaction is always the same, but unless the conditions remain the same, different amounts may appear as sensible heat, other portions disappearing as physical work. Thus, when CO_2 is formed, exactly the same amount of heat is produced in all cases—but less sensible heat is evolved in burning the diamond, the purest form of carbon, than in burning wood charcoal. In burning the diamond, physical work is performed in disintegrating the material, which work disappears from the heat product. The accurate measurement of the quantity of heat produced by a given chemical action is a problem of great difficulty, chiefly because the chemical change is accompanied by certain physical changes involving heat or work each of which requires to be allowed for before the effect due to chemical action can be rightly estimated. The measurements are made by inclosing the acting substances in a vessel called a calorimeter

surrounded by water or mercury, the rise in temperature of which indicates the quantity of heat evolved by the chemical action. The unit of heat adopted in these experiments is that required to heat one gramme of water from 0°C to 1°C. This unit for convenience is sometimes called a calor. For heat calculations the weights in chemical equations are taken in grammes. The numbers accepted by some chemists for the heats of formation of the compound gases, most commonly present in explosion, are as follows:

$CO_2 = 97{,}000$
$H_2O = 59{,}400$ when the product is taken as a gas.

That is 12 grammes of carbon uniting with 32 grammes of oxygen and forming 44 grammes of carbon dioxide will produce 97,000 calors, or will heat 97,000 grammes of water from 0°C to 1°C. The other may be read thus: 2 grammes of hydrogen uniting with 16 grammes of oxygen and forming 18 grammes of steam or vapor, will produce 59,400 calors, or units of heat. But this is not all the heat produced in this case, a portion disappears in converting the water into steam. If the product is taken as a liquid—that is, if we allow the steam to condense—we get in all about 70,000 calors.

This paper has already reached a considerable length, and a consideration of the heat relations of explosives is reserved for a future article; moreover there is a very interesting subject which the writer wishes to notice.

Chemical Theory of Gunpowder.—The chemical equation

$$2KNO_3 + 3C + S = K_2S + 3CO_2 + N^2$$

has been generally accepted as expressing the chemical theory of a gunpowder explosion, and so far, for the sake of simplicity, we have used it; but when we compare the second member with the actual products of explosion, it appears entirely inadequate. The products of explosion are much more numerous and complex. The following substances have been found among the solid products: potassium carbonate, sulphate, sulphide, hyposulphite, and sulphocyanate, ammonium carbonate, and sometimes free sulphur and carbon. The gaseous products are carbon

dioxide, nitrogen, carbon oxide, hydrogen sulphide, marsh gas and hydrogen. The apparent complexity in this list has been confirmed by the opinion* of Noble and Abel, the celebrated English investigators, who in one of their memoirs have declared that no value can be attached to any attempt to give a general chemical expression to the metamorphosis of gunpowder. They were led to this conclusion by the fact that the same powder seemed to give widely different proportions of the several solid constituents under conditions as nearly the same as possible to attain in experiment.

This discouraging dictum, coming from the projectors of the most thorough set of practical experiments ever made upon gunpowder, has not prevented several distinguished chemists from attempting to formulate a chemical theory for gunpowder. They have preferred to take the mass of facts gathered by Noble and Abel, and treat them after their own fashion. Berthelot, the great French chemist, was the first to assert that one of the products, potassium hyposulphite, did not exist as a primary product, but was formed during the analysis of the powder residue. He proposed several chemical equations, according to which powder might undergo combustion, depending upon the conditions of heat and pressure. If we suppose one portion of the powder to burn according to one equation, a second portion according to a second equation, and the balance according to a third, it is evident we can explain considerable variations in the products of one and the same powder. Berthelot's theory is more curious than useful, and we drop it to consider a much more remarkable and consistent one by an English chemist—Prof. Debus—first published in the transactions of the Royal Society in 1882. We regret that our space is too limited to give more than a brief and inadequate summary of Prof. Debus' paper.

The first difficulty encountered in attempting to apply a chemical theory to gunpowder, is that charcoal is assumed to be pure carbon, whereas it has notable amounts of hydrogen, oxygen and ash, and always contains a small percentage of water. The

*It is no more than fair to say that in one of their subsequent memoirs they have modified this opinion.

hydrogen thus introduced into the powder appears in the explosion as hydrogen sulphide, marsh gas, ammonia, and free hydrogen. Rejecting these products as well as the sulphocyanate, the amount of which is very small, we have, to be accounted for, potassium carbonate, sulphate, sulphide, and hypo-sulphite, carbon dioxide and oxide, and nitrogen.

The plan of analysis followed by Noble and Abel was that proposed by Bunsen and Schischkoff—to determine the amount of sulphide, the aqueous solution was digested with cupric oxide to convert the sulphide into hydrate. The question whether or not the oxygen of the copper compound, during the process, converted the sulphide or part of it into the hyposulphite, was settled in the affirmative by Prof. Debus, after a long and elaborate system of experiments. On this point he says, "the hyposulphite is formed in such quantities that a convenient method for the preparation of the salt might be based on the reaction." This threw out of consideration one of the products, the presence of which had always been a puzzle, since it is known to decompose at about 450° Fahr.

The point that one and the same powder will give different products of explosion under the same circumstances, is met by our author by showing that the analysis of the products does not agree in many cases with the assumed composition of the powder, and he is forced to conclude that the methods of analysis do not yield exact results, or that the composition of the powder varies from one experiment to another. On this point he says—"Gunpowder is a mechanical mixture of nitre, charcoal and sulphur. It can hardly be expected that such a mixture, even if the greatest care be taken by the manufacturer, will be perfectly homogeneous." He then gives Noble and Abel's analysis of two powders side by side with that of a distinguished chemist, showing sharp discrepancies between them. But the best proof that the same description of powder from the same works will vary much in composition, is afforded by Noble and Abel themselves. In their first memoir they assign to rifle large grain powder, carbon 10.86. In their second paper, an analysis of the same powder gives carbon 12.40. These two samples were taken from the same barrel, one from the top and the other from the bottom.

If we will consider the effect that such a difference—more than $1\frac{1}{2}$ per cent. of carbon—would have in the explosion, we will have at once a reason why the relative proportions of carbonate and sulphate should vary from one experiment to another. Indeed, the two powders here considered would have given a quantitative difference in these products almost as great as the greatest difference observed in the whole series of experiments.

In the experiments of Noble and Abel, the powder was exploded in hermetically closed steel cylinders in quantities varying from 100 to 700 grammes. The products of combustion were thus allowed to remain in contact at a white heat and in a gaseous or fluid state for 60 or more seconds after explosion.

The experiments and results of Karolyi, who fired his powder under different circumstances, when compared with the English, furnish the key to a chemical theory of gunpowder. We get not only an idea of the reactions, but the order in which they follow each other during the combustion.

Karolyi inclosed 30 odd grammes of Austrian powder in a small metallic cylinder suspended in the center of a 60-pounder shell exhausted of air and hermetically sealed. The powder was exploded by an electric current. As soon as the pressure reached a certain tension, the cylinder burst, and the products of the explosion were scattered about the space of the exhausted shell. The products were analyzed by the methods of Bunsen. Karolyi found the same products as were afterwards found by the English experimenters, and free carbon and sulphur besides, but the proportions of the several products were very different. Karolyi obtained much more sulphate and less carbonate, while the sulphide found, together with the hyposulphite formed from it durthe analysis was insignificant. The English chemists found one fourth of the potassium in the shape of sulphide. A considerable portion of Karolyi's carbon remained unconsumed. As a rule every portion of this element was burnt in the English experiments, though the English powder contained more carbon than the Austrian. Similar differences are observed in the gases. The gases obtained by Karolyi were more combustible; that is, there was more hydrogen and marsh gas and less hydrogen sulphide. The natural conclusion is, that the combustion of Karo-

lyi's powder was interrupted before its completion, and the correctness of this view is sustained when we consider what would have been the result if the products of Karolyi had remained in fluid contact for some time at a red heat, instead of being suddenly cooled and in great part congealed by contact with the cold walls of the iron shell. The free carbon and hydrogen and the constituents of the marsh gas (CH_4) would have been burned at the expense of the oxygen of the sulphate, and the quantity of the latter diminished, sulphide being produced in its stead. The free sulphur would have decomposed the carbonate with the production of sulphate and sulphide, and in short the products would have arranged themselves in the proportions we find in the Noble and Abel experiments.

After making various corrections, Prof. Debus deduces the following equation to represent the mean of the results obtained by the English experimenters, in which the composition of the powder as represented by the first member is calculated from the products of explosion—

$$\left.\begin{array}{l}16KNO_3+1.34N\\+21.35C+1.34H\\+6.63S\end{array}\right\}=\left\{\begin{array}{l}4.98K_2CO_3+13.13CO_2+0.84S\\+0.90K_2SO_4+3.23CO+0.67H_2S\\+2.10K_2S_2+17.34N\end{array}\right.$$

Rejecting the nitrogen and hydrogen in the first member and part of the sulphur, some of which was found united with the iron of the apparatus, we can simplify this as follows:

$$\begin{array}{rl}16KNO_3 + 21C + 5S = & 5K_2CO_3 + 13CO_2\\ & 1K_2SO_4 + 3CO\\ & 2K_2S_2 + 8N^2\end{array}$$

The equation deduced for Karolyi experiments, if we reject the free sulphur and carbon, is

$$16KNO_3+13C+5S=3K_2CO_3+5K_2SO_4+9CO_2+CO+8N^2$$

The Austrian and English powders do not differ very much in composition. This last equation represents, therefore, the first stage and the one above it, the completed combustion of gunpowder. Prof. Debus sums up his result as follows:

" The combustion of gunpowder accordingly consists of two " distinct stages: a process of oxidation which is finished in a

" very short time, occupying only a very small fraction of a " second, and causing the explosion, and during which potassic " carbonate and sulphate, carbonic acid, some carbonic oxide " and nitrogen are produced, and a process of reduction, which " succeeds the process of oxidation and requires a comparatively " long time for its completion. As the oxygen of the saltpetre " is not sufficient to oxidize all the carbon to carbonic, and all " the sulphur to sulphuric acid, a portion of the carbon and a " portion of the sulphur are left free at the end of the process " of oxidation. The carbon so left free reduces during the sec- " ond stage of the combustion, potassic sulphate, and the free " sulphur decomposes potassic carbonate. Hydrogen and marsh " gas, which are formed by the action of heat upon charcoal, " likewise reduce potassic sulphate and some hydrogen com- " bines with sulphur, forming sulphureted hydrogen."

Prof. Debus supposes all gunpowders to burn according to the equation—

$$16KNO_3+13C+5S=3K_2CO_3+5K_2SO_4+9CO_2+CO+8N_2$$

This represents the first stage, that of oxidation. If the composition be such (as is generally the case) that there is free sulphur and carbon left at the end of this stage, and the combustion is not interrupted, then the second stage is represented by the following:

$$\left.\begin{aligned} 4K_2CO_3 + 7S &= K_2SO_4 + 3K_2S_2 + 4CO_2 \\ 4K_2SO_4 + 7C &= 2K_2CO_3 + 2K_2S_2 + 5CO_2 \end{aligned}\right\} \text{(C)}$$

His arguments in favor of Equation (B) are very strong. It happened that Karolyi used two powders—a rifle and a cannon powder—the latter of which contained 3 atoms more of sulphur for every 16 molecules of nitre, yet the products produced during the first stage from the two powders were almost identical and those represented by Equation (B).

The heat relations of the principal products in Equation (B) are remarkable. If we assume for the heat of formation of the carbonate, sulphate, and carbonic acid, the following values:

$$K_2CO_3 = 279540 \text{ cal}$$
$$K^2SO_4 = 344640 \text{ "}$$
$$CO_2 = 97000 \text{ "}$$

which are given on the authority of Thomsen, we obtain—

$$3 \times 279540 = 838620$$
$$5 \times 344640 = 1723200$$
$$9 \times 97000 = 873000$$

Now 838620 : 1723200 : : 873000 = 1 : 205 : 1.04
or nearly 1 : 2 : 1

ratios, which are very remarkable.

If Prof. Debus' reasoning be correct, equation (B) represents not the strongest but the most combustible mixture that we can make. There being no free carbon or sulphur left in the products it should give a quick, sharp, clean explosion—the properties required in sporting powders. If we make an allowance of four per cent for the hydrogen, oxygen, ash and moisture contained in gunpowder, and calculate the first member of equation (B) to 100 parts, we get for the composition of an ideal sporting powder:

Nitre	80.31
Sulphur	7.95
Charcoal	11.74
	100.00

The exact composition of high grade sporting powder is one of the most precious secrets of the manufacturer; still several noted powders cited by Prof. Debus closely approach the above formula.

The equations (C) representing the second stage of the combustion of certain powders are worthy of study. In the first place, if we calculate the heats of formation we find that these reactions are endothermic. Heat is consumed and not evolved by them.

This heat lost is converted into mechanical work in the evolution of gas. It seems to me, and I do not wish to make Prof. Debus responsible for the idea, that this point deserves special consideration. This stage consumes more time and is seldom completed except under such exceptional circumstances as those which obtained in the hermetically closed cylinder of Noble and Abel. The effect of these endothermic reactions in gunnery

practice must be to render the explosion less violent—to temper in a measure the brutal character of the blow.

By Prof. Debus' figures, a powder containing $16KNO_3+21C+7S$, which represents approximately service gunpowders, will have 8C and 2S, which will not participate in the oxidizing stage of the explosion—for the time being therefore nearly eight per cent of the powder will act as so much dead matter to impede and retard the combustion of the rest. When the violence of the blow is partially expended this eight per cent will react upon the products first formed, and by a conversion of heat into mechanical work will prolong the action upon the projectile.

We have seen that the sharp, quick nature of sporting powder is largely due to its composition, the characteristic of which is a large proportion of nitre. In blasting powders the case is reversed and the carbon and sulphur are largely in excess. The effect of this composition is seen in the slow, lifting character of the powder as contrasted with sporting. The proportion of carbon and sulphur left out of the first reaction is so considerable that the shock is no longer a sharp blow, but rather a pushing or lifting effect which is extended over a considerable period of time by virtue of the large amount of gas contributed by the subsequent reactions.

The subject is one which should be studied in connection with the preparation of powder for heavy guns.

Professor Debus' paper has been reprinted in this country by the U. S. Naval Institute and can be found in No. 23 of its proceedings. Whether regarded simply as an example of deductive reasoning, or as the most valuable contribution to the theoretical chemistry of gunpowder ever published, it is equally admirable.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II — APRIL, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

April 3, 1885.

President Mendell in the Chair.

Minutes of the preceding meeting were read and approved.

Wm. H. Radford was proposed as a non-resident member by Aug. J. Bowie, Jr., L. L. Robinson and Sanford Robinson.

A paper by Wm. R. Quinan, entitled "A Talk About Explosives," was read.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XIX.

VOLUME II — MAY, 1885.

NOTES ON EARTHWORK.

By GEO. J. SPECHT, M. Tech. Soc.

Read May 1, 1885.

It is not the intention of the writer in presenting this paper, to call attention to any new or startling facts, but simply to note some few points of interest in the ordinary experience of the Civil Engineer. The number of great and novel engineering works is so limited that it is not given to many to have charge and direction of them; but though highly interesting, the lesson they convey is not of as great value to the engineer as that obtained by daily practice in the field. The following notes are therefore submitted to the consideration of the members of this Society.

The Sutter County Land Company owns a tract of land containing 5,000 acres, located in Sutter County, about 16 miles south of Marysville, 8 miles east of the Sacramento river, and 6 miles west of the Feather river. It occupies nearly the centre of the Sutter basin, which plays a very important part in the drainage of the northern part of the State, serving during periods of flood as a relief basin to the Sacramento and Feather rivers, whose waters, owing to the insufficient capacity of the river channels, are backed up from the lower end of the basin.

Along the west side of Feather river to a point nearly opposite the mouth of Bear river a levee has been built, which was constructed and is maintained by an organized levee district. Below this point there are only short stretches of private levees, which do not offer an effective protection to the land. During the high water season, therefore, the Feather river overflows its banks above Nicolaus, and submerges a large area of Sutter basin. The channel of the Sacramento river from Butte Slough to Knight's Landing is sinuous and narrow, and according to the State Engineer, has not a sufficient capacity to carry off more than half of the water brought down to it in ordinary high water. It relieves itself by overflowing into Butte Slough, a depression in the Sutter basin, running nearly parallel with the Sacramento river, and submerges the Sutter basin, already partly filled by the overflow of the Feather river, thereby increasing the height of the water and the area overflowed. In the absence of any officially prescribed system of levees, every land owner constructs his own embankments without considering what their effect may be upon the drainage of the whole valley.

The levees of the Sutter County Land Company, whose property is the vanguard of the entire valley, being located the farthest to the south, will protect a much larger area of land than is embraced in the company's tract; but though these, which are to resist the heaviest attacks, must be higher and stronger than those of adjoining land owners, the company has received but little or no assistance towards their construction. As these levees are not exposed to the constant wash of a river current, their only service is to protect the land against the water flowing into the Sutter basin at periods of flood, when the basin forms a large inland lake. During the winter months, the prevailing south and southeast winds cause waves, which are very destructive to the levees.

The levees built in this section of the country are constructed usually with an outside slope of 3 : 1 or 4 : 1, and an inner slope of 1.5 : 1 or 2 : 1, and a top width of from 6 to 10 feet. The earth which is used to form the embankment is taken from both sides of the levee, and is put in place by means of scrapers.

The Sutter County Land Company's levee, as built at present,

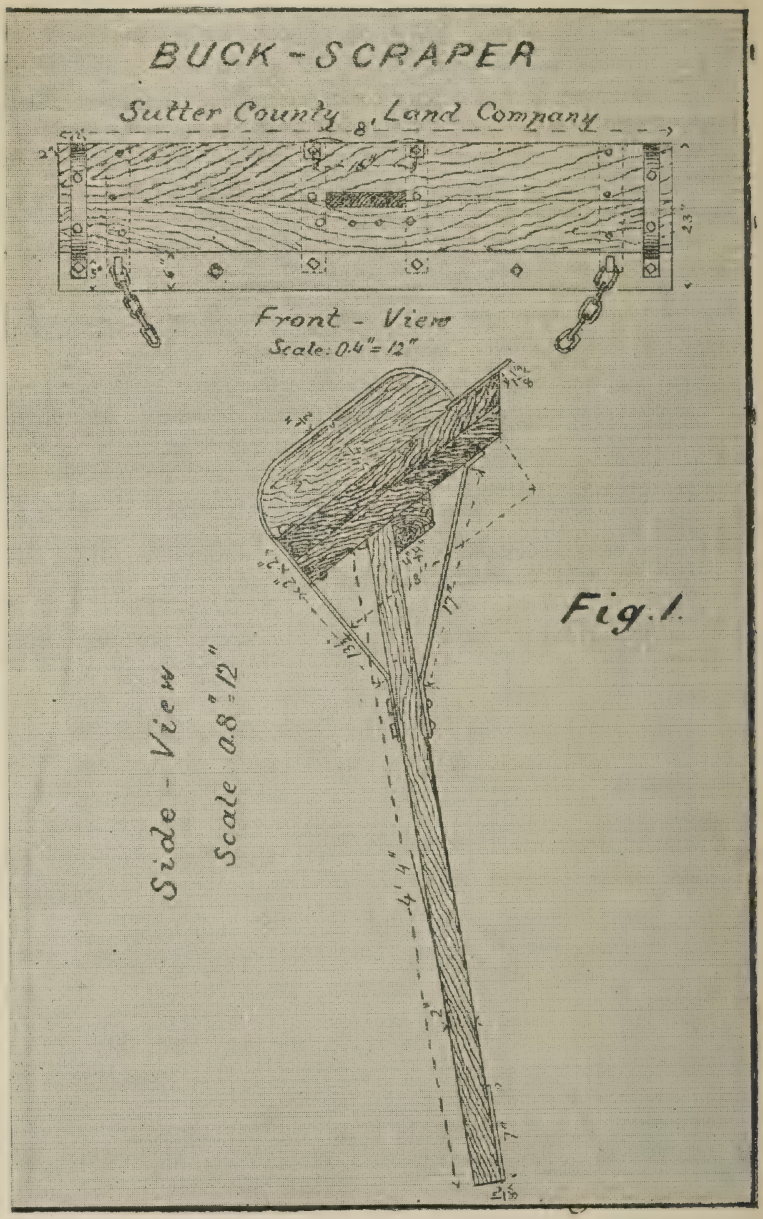
is 6′ wide on top, with slopes of 3 : 1 on the inside, and 4 : 1 on the outside; its height varies from 6 feet to 14.5′. This type will probably be changed gradually to a 10′ wide crest, with slopes 6 : 1 outside, and 2 : 1 inside. Bermuda grass will be planted on the slopes to protect them from washing, and a double row of willows will be set on the outside of the borrow-pits.

In 1884, work was commenced on August 19th; but it was interrupted December 16th by a heavy rainfall, and consequent overflow, the levee not being completed. Shortly after this storm the entire Sutter basin was overflowed.

In the construction of the levee just referred to, buck-scrapers and a few dump-scrapers were used. The buck-scrapers were 8′ long and 23″ wide from outside to outside. The other dimensions can be seen in Sketch No. 1. Four horses are required to move one scraper. The driver stands on the end of the tail-board, pressing by his weight the edge of the scraper upon and into the ground. This weight was not properly applied in the scrapers used, and two additional men were required to weight them down during the time of filling. The horses pulling ahead, earth accumulates in front of the scraper, and it is moved and deposited where required. To dump the earth, the driver steps off the tail-board and the forward pull of the horses turns the scraper on its lower edge and empties it. The scraper then runs on its side-boards over the deposited earth to the other side of the levee and into the borrow-pit. The side-boards are protected by flat iron, ½″ thick. In the pit the driver takes hold of the tail-board, presses it down upon the ground and steps upon it, and again proceeds as above described.

A certain number of scrapers, varying according to the requirements, were worked in one gang, continuously moving from one side of the levee to the other, an operation by which the earth is well packed. The first load is taken near the foot of the slope, and the circuit enlarged with each trip until that particular section of the pit is scraped clean. In order that the work may proceed without interruption, it is absolutely necessary to have sufficient ground plowed ahead of the scraper gangs.

The average height of the levee is 12 feet; the average width


BUCK-SCRAPER
Sutter County Land Company
8'
Front - View
Scale: 0.4" = 12"
Side - View
Scale 0.8" = 12"
Fig. 1.

of its base 90′; the borrow pits are about 100′ wide each. Subsequently, when the levee became higher, the ground was not plowed for the entire width of the pit, but only about 70′ wide, which gave sufficient earth with a shorter haul. The soil on which the levee was to be built was plowed before any earth was dumped upon it, so that the natural ground and the levee would be properly consolidated. A levee partly finished in 1883, was also plowed before new earth was put upon it. It is necessary to observe this precaution, for when last highwater overflowed all the levees in that neighborhood and washed a considerable quantity of earth from their slopes and crest, those where the surface of the old work of the previous year had been plowed before new earth was put on, settled very evenly, and form now a solid base for the work that remains to be done, while in the levees where the original surface had not been plowed, the newly added earth has been washed down entirely, and the old slope is exposed again.

The levees were built in successive layers of about equal depth. In this way the earth was well packed down by the teams moving over it. As the working capacity of a team rapidly decreases with the increase of the slope, it is advisable to move as much earth as possible upon gentle slopes, which is accomplished in the method adopted. About 90 per cent. of the whole amount of earth was moved on a slope of less than 4 : 1.

During the construction of these levees, the question of the proportions between the bulk of earth in cut and in fill was investigated. The measurements show in all cases an increase in bulk, that is, taking the cross-sections of the borrow pits and of the levee *simultaneously*, the levee showed a larger area than the two borrow pits together. The proportion varied in different kinds of earth. This question must not be confounded with that of final settlement, which sometimes even continues for a long time after the embankment is finished, and must be provided for in the construction by increasing the embankment beyond the limit of the final cross-section desired. There are many causes which influence this settlement, such as the character of the soil of which the embankment is composed, and upon which it is built; the weather during the progress of the work; the mode of con-

struction; the height of the embankment, etc. For each particular case, a separate coëfficient of permanent settlement must be established, varying from 2% to 12% of the height. The rule of the St. Gothard Railroad, in Switzerland, was to increase the height in earth embankment by $\frac{1}{12}$ of its final elevation and in rock embankment by $\frac{1}{15}$. The width of earth embankments was increased on both sides by $\frac{1}{15}$ of the height of the embankment.

As the increase in bulk of earth is liable to lead to disputes, it is best to base contracts on measurements in cut or pit, and to stipulate certain proportions for cases where the necessity requires the measurement to be made in fill, and to fix the time when it shall be made. The Austrian North Western Railroad, the construction of which is acknowledged to be above criticism, adopted the rule "that if it should be necessary to measure the material in a fill instead of in a cut, as usual, the amounts in fill must be reduced by 30% in rock, and by 10% in all other kind of soil."

The Imperial Railroad Department of Austria has this clause in its contracts: "If the necessity arises to measure earth and rock in fills, made from material taken from the adjoining cuts or borrow pits, instead of in cut, the cubic contents of the fill must be reduced 30% in rock and 20% in embankments made of earth in layers."

In making the final estimates of the St. Gothard Railroad, the quantities in cut were increased by 3% in earth and 8% in rock, to equalize the amounts needed for embankments.

In the levee work, under the direction of the writer, the following proportions were observed:

9,398 cubic yards in cut gave 9,470 in fill (ground: heavy adobe, measured three weeks after finished).

10,000 cubic yards in cut gave 10,290 in fill (ground: adobe and sandy loam).

29,000 cubic yards in cut gave 30,330 in fill (ground: the same as last).

53,350 cubic yards in cut gave 58,350 in fill (ground: sandy loam with small amounts of adobe and hard pan; this is the largest increase found).

202,634 cubic yards in cut gave 208,915 in fill (this represents the work of three months).

The final conclusion of the writer is, that no general coëfficient can be established to express the proportion of earth or rock in place to earth or rock in fill. It is different with different kinds of material, and with the different methods of building the embankments.

A. Von Kaven, President of the Royal Polytechnic Institute in Aix-la-Chapelle, says in his book on "road building":

"The volume of an embankment and its height are different "at different times. European experience in road building is "that, after the fill is finished, the earth used therein occupies a "larger space than in the ground:

"In clay and loam	$\frac{1}{48}$	more.
"In soft sandstone	$\frac{1}{32}$	"
"In hard clay	$\frac{1}{20}$	"
"In rock	$\frac{1}{13}$ to $\frac{1}{10}$	"

"During the construction of the Rhine-Nahe Railroad, it was "observed that the increase in bulk from cut to fill was in "the beginning 25 per cent. in rock, but when from one quarter "to one third of the total bulk of the embankment was built of "clay, put in simultaneously with the rock, the final increase in "embankment, after the same was finished, was only 9 per cent. "There are certain kinds of earth and certain conditions during "the time of building, when the embankment occupies less "space than the earth measured in place. For instance, if the "earth is wet, or if it is tamped, etc. The French engineer, "Graeff, says that 1 cubic meter of rock measured 1.5 to 1.6 "whenever in fill, but as considerable earth was used with it to "fill the intermediate spaces, 1 cubic meter cut made 1 cubic "meter fill in a general average."

"In building the Marne-Rhine canal the loose earth was care-"fully tamped and 1 cubic metre embankment required 1.10 to "1.25 cubic metre in cut. He advises, therefore, not to count on "any difference, but to accept cut and fill alike, and allow only "in very light sand a decrease of one-tenth in fill.

"According to a series of observations—

"100 cubic feet of loose sand make 115–120 cubic feet in fill.

"100 cubic feet of clay and coarse sand make 122 cubic feet "in fill.

"100 cubic feet of hard clay, lias, make 124 cubic feet in fill.

"100 cubic feet of clay mixed with cobble-stones make 126 "cubic feet in fill.

"100 cubic feet of decomposed rock, solid gravel banks, make "128 cubic feet in fill.

"100 cubic feet of rock (can be picked) make 130 cubic feet "in fill.

"100 cubic feet of rock, requiring blasting, make 134–150 "cubic feet in fill."

Henz, the author of a Manual on Earthwork, states as the result of a large number of observations of actual work, that the permanent increase in volume from cut to fill is—

In sandy soil	1–1.5	per cent.
In clay and light soil	3	"
In marl	4–5	"
In hard clay	6–7	"
In rock	8–12	"

J. Trautwine in his pocket-book says on page 630, edition of 1876: "Although earth when first dug and loosely thrown out, swells about $\frac{1}{5}$ part, so that a cubic yard in place averages about $1\frac{1}{5}$ or 1.2 cubic yards when dug; or 1 cubic yard when dug is equal to $\frac{5}{6}$ or 0.8333 of a cubic yard in place; yet when made into embankment it *gradually* subsides, settles or shrinks into a less bulk than it occupied before being dug."

This refers undoubtedly to the permanent settlement for which proper allowance in the building of embankments, by increasing their dimensions, must be made.

The capacity of one buck-scraper during the construction of the Sutter County Land Company's levee was as follows:

70,000 cubic yards were moved in 1,277 scraper-days, or one scraper moved per day about 55 cubic yards.

294,000 cubic yards were moved in 3,249 scraper-days, or one scraper moved per day 90.5 cubic yards.

The small capacity in the first case was due to the inexperience of the contractor as well as of the teamsters, and to the fact that it was an old levee, partly finished the year before, which necessitated a higher pull.

The total work done was 364,000 cubic yards, moved in 4,526 days, or 1 scraper moved per day 80.5 cubic yards in an average.

In the cost of the work, the sums given in reference to feeding of horses and boarding of men are not quite authoritative, but the usual prices charged by livery stables and farmers have been used.

In October were 22 working days. The expenses were:

Hire of horses, 272 horses @ 50 cents per day	$2,992 00
Wages of men	3,750 00
Feeding of horses @ 35 cts. per day, 31 days.	2,940 00
Boarding of men	1,488 00
	$11,170 00

Number of cubic yards moved	116,000
Cost of one cubic yard	9.63 cents.

In November were 25 working days. The expenses were:

Hire of horses, 310 horses @ $0.50	$3,875 00
Wages of men	3,996 00
Feeding of horses, (30 days)	3,255 00
Boarding of men	1,440 00
	$12,566 00

Number of cubic yards removed	110,000
Cost of one cubic yard	11.4 cents.

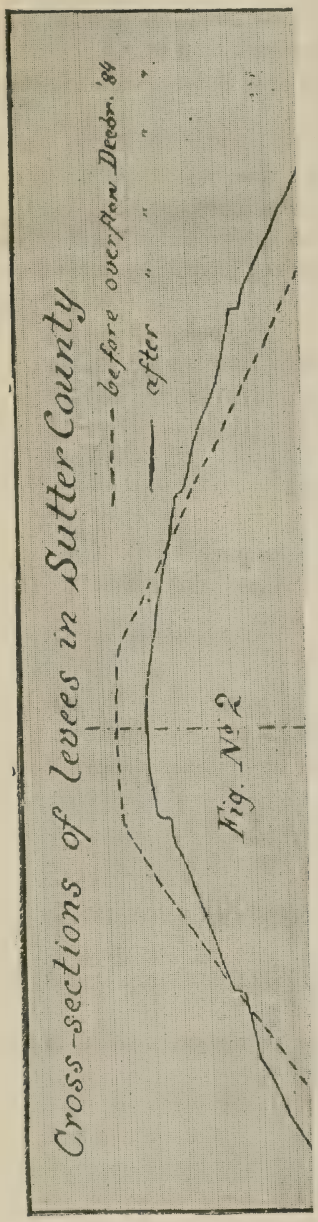
This shows the rapid increase of cost with the increase of height of levee.

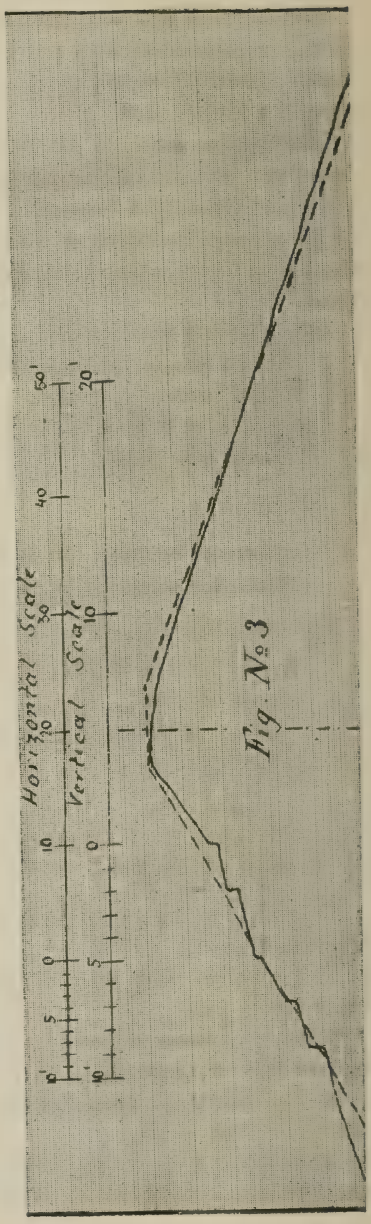
The contract price was 12 cents per cubic yard, measured in the borrow pit.

The levees were not completed, as the heavy rains in December caused the overflow of the entire Sutter basin.

Sketch No. 2 shows the cross-section of the levee before and after the high water.

Sketch No. 3 shows the cross-section of another levee of the same reclamation, before and after the last high water.


Cross-sections of levees in Sutter County
- - - - - before overflow Decbr. '84
——— after " " "
Fig. No 2


Horizontal Scale
Vertical Scale
Fig. No 3

The latter was built with an outside slope of nearly 6 : 1; the same was not washed by the waves to any extent, while its 3 : 1 inside slope was badly damaged by waves, which proves that any slope steeper than 6 : 1 should not be used in these levees.

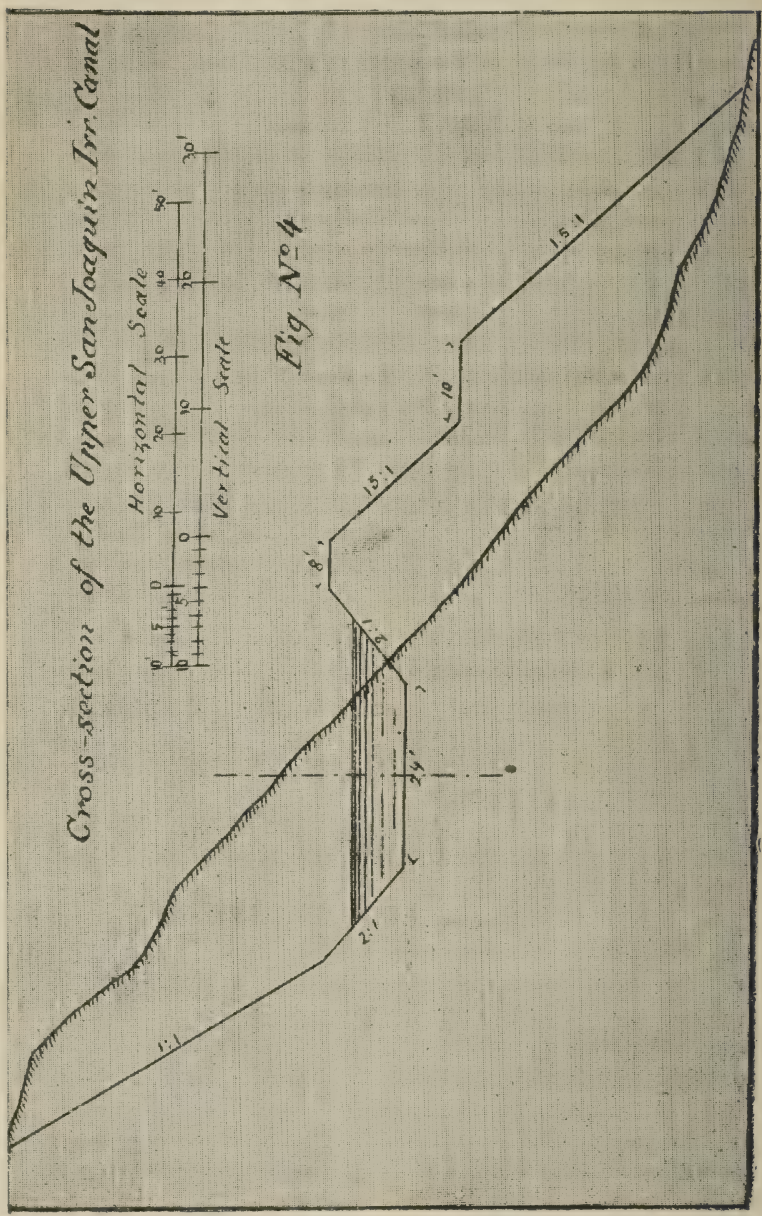
A break occurred in another levee, principally caused by bad location, forming a sharp prominent corner. Such prominent corners and turns should be avoided by all means. In connecting two levees of different directions with each other, flat curves should be used, even at a sacrifice of arable land, and the levee should then be strengthened by a flatter outer slope, greater top width, and higher elevation This break was repaired by Chinese labor and wheelbarrows. Seven wheelbarrow loads made one cubic yard. Average haul, 208′; vertical raise, 7′; ground, moist adobe, requiring frequent cleaning of shovel and barrow. Average time of one round trip was 7½ minutes; time required to move 1 cubic yard, 52½ minutes (counting from the moment when shoveling in the pit commenced to the same time after a complete round trip). Average work of one wheelbarrow per 9½ actual working hours, 10.8 cubic yards. The cost was as follows:

13 Chinese @ $1.50	$19.50
1 white foreman and his board	2.50
	$22 00

Work per day, 10 wheelbarrows, 108 cubic yards; hence cost of one cubic yard, 20.3 cents

In these expenses, as well as in the above ones given, nothing has been allowed for wear and tear, and no percentage added for the cost of the plant.

Several years ago the writer was connected with the construction of the Upper San Joaquin Irrigating Canal in Fresno County. The canal runs for several miles along a high bluff, which is apparently the shore of the old river channel. This bluff, which is composed of sediment, sand and hard pan, 2 : 1 to 1. 5 : 1 for about 75 per cent. of its length. There is no rock, and the hard pan occurs in strata of from a few inches to one foot in thickness, separated by quicksand. The hard pan is sufficiently solid to stand with a slope of 0.5 : 1, while the underlying sand rests only at 2 : 1 or 3 : 1. This necessitated flatter slopes than the hard pan above required. Where the hard pan cropped out, it was very hard, while at some depth below the surface, it could be picked, and still deeper be plowed.


Cross-section of the Upper San Joaquin Irr. Canal
Horizontal Scale
Vertical Scale
Fig. No 4
15:1
15:1
1:1
2:1
8'
10'
24'

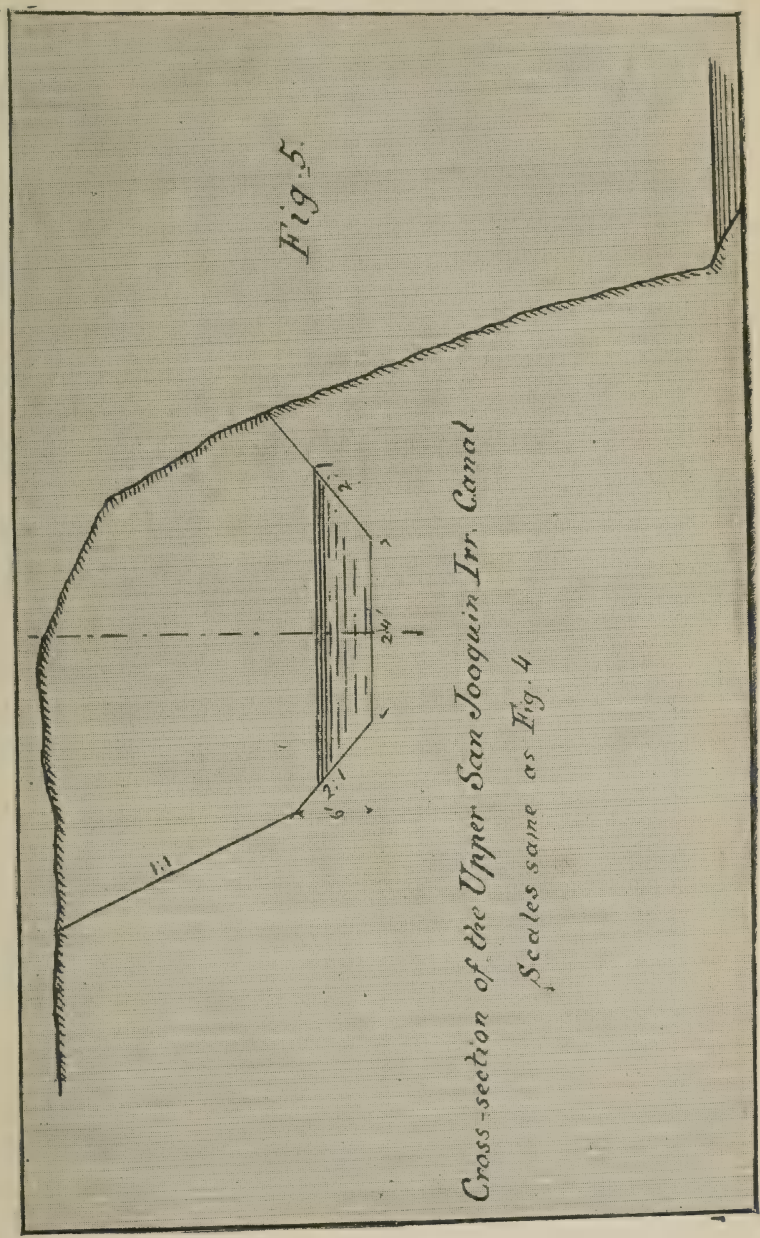
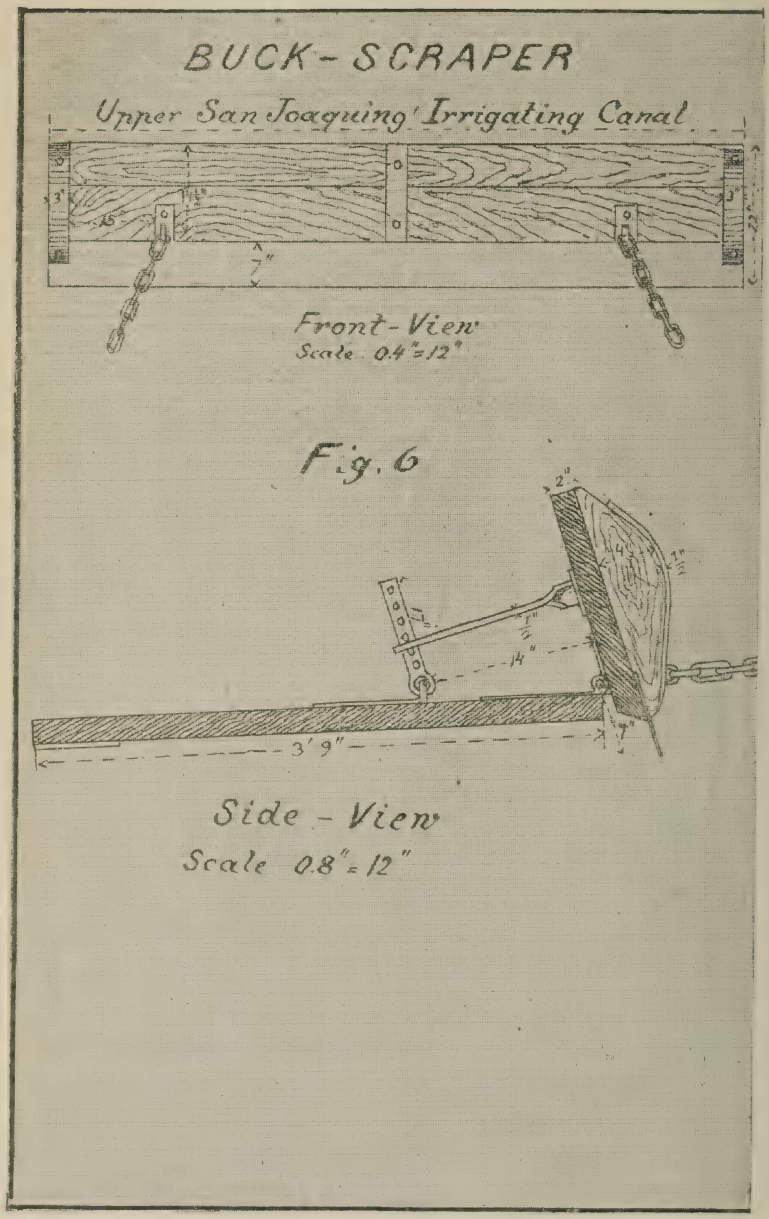


Fig. 5.
1:1
2:1
24'
Cross-section of the Upper San Joaquin Irr. Canal
Scales same as Fig. 4


BUCK-SCRAPER
Upper San Joaquin Irrigating Canal
3"
1½"
7"
2"
Front-View
Scale 0.4"=12"
Fig. 6
2"
14"
1½"
1½"
14"
3'9"
7"
Side-View
Scale 0.8"=12"

Sketches 4 and 5 show two characteristic cross-sections of this canal. The work of excavation and of building lateral embankments was done by buck scrapers and dump scrapers. The dimensions of the first can be seen in sketch No. 6.

As all the loads had to be moved down hill, the work performed daily by one scraper was large. Observations showed that, with a total length of the round trip of 400′ and a vertical distance of 40′, in 9 actual working hours one scraper made 95 round trips, carrying at each 1.3 cubic yards. All the conditions were very favorable. This is the average of 1000 observations. The maximum load observed was 1.64 cubic yards. Later observations of the same piece of work showed an average daily capacity of one scraper of 128 cubic yards.

The dump scraper moved on an average 4 cubic feet per load. They were used principally to move the earth to the edge of the canal, from where it was taken by the buck scrapers. In a round trip of 225′ length, one dump scraper moved 18 cubic yards per 9 hours actual work. Ground was very favorable.

The cost of this work was as follows:

Month of November, 1882:

Daily expense of one buck-scraper:

4 horses, hire @ 37½ cents	$1.50
4 " feed @ 40 cents	1.60
1 driver, wages (1.15) and board (40 cents)	1.55
	$4.65

Daily expenses for one dump-scraper:

2 horses, hire, @ 37½ cents	$0 75
2 horses, feed, @ 40 cents	0 80
1 driver, wages and board	1 55
	$3 10

Daily expenses for one six-horse plow:

6 horses, hire and feed	$4 65
2 men, wages and board	3 10
	$7 75

Daily expenses for one four-horse plow:

4 horses, hire and feed	$3 10
2 men, wages and board	3 10
	$6 20

General expenses for the month of November:

1 foreman	$70 00
½ bookkeeper ($70)—attending to two camps	35 00
1 blacksmith, @ $3	78 00
1 hostler	30 00
2 Chinese cooks	60 00
Board for these men	66 00
Feed for 4 work horses	48 00
	$387 00

for 30 days, or $12.90 per day.

In this period of 27½ days were moved 55,925 cubic yards. This required—

29.5 six-horse plows, @ $7.75	$228 63
15.5 four-horse plows, @ $6.20	96 10
409 buck-scrapers, @ $4.65	1,901 85
130.5 dump-scrapers, @ $3.10	404 55
33 men on dump, @ $1.55	51 15
328 Chinese, @ $1.15	377 30
18 Chinese bosses, @ $1.75	31 50
	$3,090 98
General expenses during the same period (Octobor 30 to November 30)	406 35
Cost of moving 55,925 cubic yards	$3,497 33

or cost of one cubic yard, 6.25 cents. The contract price for this work was 9 cents.

Month of January, 1883. (January 8th to 31st.)

301 buck-scrapers, @ $5	$1,505 00
86.5 dump-scrapers, @ $3.30	285 45
62.5 six-horse plows, @ $8.25	515 63

2 four-horse plows, @ $6.60	$13 20
2 V-scrapers, @ $11.55 (8 horses, 4 men)	23 10
522 Chinamen, @ $1.15	600 30
52 white laborers, @ $1.65	85 80
22 days' general expenses, @ $14.55	320 10
For emergencies	51 42
Total	$3,400 00

The increase in the prices is due to a closer analysis of the cost of feeding the horses and to the addition of one hostler.

During that period 42,241 cubic yards were moved; therefore the cost of one cubic yard was 8.04 cents.

The average capacity of one scraper per day was 131 cubic yards. A large portion of the excavated earth had to be moved several times, as the canal was in a thorough cut on a high bluff (fig. 5). The moving was done by buck- and dump-scrapers to the edge of the bluff, and then pushed over the latter by plows and a V-scraper.

The cost of one cubic yard during the first five days of January was 7.24 cents.

During these days the ground worked was on a side hill with an average natural slope of 2.5:1; the longest distance from top of slope to bottom of embankment averaged about 100′; very little hardpan was met during this period, but afterward a large amount was struck, which accounts for the increase in price above mentioned.

During February, 1883, 80,000 cubic yards were moved at a total cost of $8,684, or price of one cubic yard, 10.8 cents; this included $1,000 for Judson powder.

In reference to plowing we have the following items: Observations of January: 1 eight-horse plow kept 12 buck-scrapers busy; the price for plowing the ground, reduced to the cubic yard moved, was 0.70 cents per cubic yard. In another section the cost was 0.58 each. Observations in February: 1 eight-horse plow and 1 six-horse plow were needed to keep 17 buck-scrapers employed in a length of 1,500′ of canal. These 17 scrapers moved 2,210 cubic yards, the loosening of which represents the work of the two plows. The soil was loose sand, and

only about for a length of 200 feet hardpan. The expense for plowing was $18.25, or 0.83 cents per cubic yard. Later in February more hardpan was encountered and the cost of plowing increased to 1.05 cents per cubic yard, and later on yet to 1.25 cents.

In connection with the question of earthwork, a method may be mentioned which is in general use in Europe, though it is not known here apparently. In making estimates for railroads and inviting bids for contracts, the European custom is, that the railroad company makes a very detailed estimate; and the result of this—in detail, as well as in general—is made the base for the contractor's bid. In the call for bids, the cost estimated by the company is given, and contractors are invited to bid so many per cent. below or above it. This method requires a very carefully made estimate, based on detailed studies of the ground, assisted by trial-pits; very often, especially in tunnel-work and foundations, extensive trials are made. The results of all these studies are at the disposal of the contractors; they comprise a longitudinal profile, a complete set of cross-sections, a distribution-profile, detail plans of all the bridges, culverts, road-crossings, retaining walls, etc.; a map of the railroad, list of prices for labor and material, as ascertained by the company; in fact all papers and documents necessary for an intelligent bid.

Among the documents mentioned above, is one called "Distribution of Masses," or "Distribution-Profile." This is a graphical representation of how to dispose of the material gained in cuts and how to make embankments. The method is as follows:

Draw a horizontal line, dividing the paper into two equal parts, and representing a dividing line between cut and fill; mark upon this line the distances where the cross-sections have been taken and erect perpendicular lines in these points, for cuts above and for fills below the line. Mark upon these lines the areas of the respective cross-section, according to a certain scale—say one square metre equal to five millimetres—connect the ends of these perpendiculars by straight lines. Then the areas so formed represent the cubic contents of each cut and fill. The value of these areas are determined by planimeter. The excavations of the

foundations of bridges, culverts, slope-ditches, etc., and the amounts needed for road-crossings, or similar purposes, are also determined and platted in the distribution profile at their proper places. Then the distribution of the earthwork is made, which is best explained by an actual example. The sketch, No. 7, represents a section of 1800 in (5704′) length.

The cuts, excavation for foundations and borrow-pits are numbered successively from division 8 to division 19. The fills are not numbered. The dotted lines show the lines of separation between loose ground and solid rock. The excavation of cut No. 8 has to serve to make the fills adjoining it above and below. The fill above requires 5,504 cubic meters; a part of this will be made by earth gained in the cross-sections themselves by lateral transportation, another part by the material gained from the foundations of culverts and from the correction of the water-courses, the remainder will be taken from cut No. 8.

The remaining material of cut No. 8 is then used for the embankment above it. The foot of the latter, being exposed to the river current, has to be secured by rip-rap, therefore the rock gained in the cut must be reserved for that purpose. The cut No. 8 contains 16,657 cubic meters, of which 8,573 are loose material and 8,084 cubic meter rock. Then the length of the haul was determined by establishing the center of gravity of each area and scaling the distance between these. The center of gravity of irregular areas was determined by cutting the areas out of card-board, then suspending them from one of the corners on a fine needle, placed in a perpendicular line, drawn on the wall of the office. The point where the opposite side was intersected by this perpendicular line was marked upon the card-board and connected with the needle point; this operation was repeated for another side. The point of intersection of the two lines gives the centre of gravity of that area. The points so ascertained were then transferred to the distribution profile and the distances between them, measured by scale, were adopted as the length of haul.

The embankment between the cuts 8 and 10 cannot be filled entirely from the adjoining cuts, but a part of it has to be filled from a borrow-pit.

This one example is sufficient to explain the method, which is certainly an interesting one, and which, in spite of its seeming complications, is very simple and is of the greatest assistance in estimating the cost of a railroad and in furnishing an intelligent, accurate base for contractors to bid on.

For further explanation, see appendix.

A different system of "distribution-profiles" will be explained in a future paper.

APPENDIX.

Explanation of Sketch No. 7.—The areas above the centre line are those of cuts, borrow-pits, excavation of foundations for bridges, culverts, rip-rap, etc. The areas below are those of fills and deposits of surplus earth. The centres of gravity are indicated by small circles, the curved lines connecting them indicate the haul; the figures written along them give the number of cubic meters in cut (C) and in embankment (E), and the length of the haul (H) in meters. $C\left\{\begin{smallmatrix}E\\R\end{smallmatrix}\right.$ means cut $\left\{\begin{smallmatrix}\text{earth}\\\text{rock}\end{smallmatrix}\right.$. Where R stands in place of E, it means rip-rap.

The following tables give the items how the excavation of each cut is disposed of, and how each embankment is built. It is customary to write these items on the distributed profile itself; but to make the latter more distinct, they are here written in a separate list.

The words "from cross-sections" in this list mean, that the railroad are partly in cut and partly in fill, and that the earth from the cut is hauled laterally to make the fill in the same cross-section. The entire example is given in metric measure.

The material from excavations is to be used as follows:

No.	Description.	Location from Stat.	Location to Stat.	Cubic Meters in Place.	Length of Haul.	Percentage of Increase.
8	Cut, 7+855 to 8+175.					
	Embankment	8 + 160	8 + 190	1,112	40	3
	Rip-rap	8 + 170	8 + 220	3,308	90	8
	Embankment	8 + 190	8 + 235	2,876	215	8
	"	8 + 190	8 + 235	5,394	215	3
	"	7 + 800	7 + 870	1,900	80	8
	"	7 + 800	7 + 870	2,067	80	3
				16,657		
9	Excavation for Rip-rap, 8+170 to 8+300.					
	Cross-sections	8 + 170	8 + 300	838	10	3
				838		
10	Excavation for Retaining Wall, 8+370 to 8+495.					
	Embankment	8 + 277	8 + 290	1,778	150	3
				1,778		
11	Cut, 8+280 to 8+400.					
	Embankment	8 + 300	8 + 320	497	55	3
	Cross-sections	8 + 350	8 + 400	500	10	3
	Embankment	8 + 290	8 + 300	431	10	3
	Rip-rap	8 + 270	8 + 300	888	65	8
	"	8 + 220	8 + 250	762	100	8
				3,078		
12	Borrow-pit in Talus of Mountain Stream, 8+360 to 8+500.					
	Cross-sections	8 + 360	8 + 500	9,017	40	3
	Embankment	8 + 270	8 + 277	983	130	3
				1,000		

No	Description.	Location from Stat.	Location to Stat.	Cubic Meters in Place.	Length of Haul.	Percentage of Increase.
13	Cut, 8+470 to 8+580.					
	Rip-rap	8 + 580	8 + 645	4,169	90	8
	In cross-sections..	.....	.....	813	15	3
				4,982		
14	Excavation for Rip-rap, 8+580 to 8+690.					
	Embankment.....	8 + 600	8 + 710	1,691	35	3
				1,691		
15	Excavation from Improvement of Marchlis-bach.					
	Embankment.....	8 + 850	8 + 890	3,012	110	3
	Rip-rap	8 + 780	8 + 810	1,697	65	3
	"	8 + 625	8 + 645	1,707	120	3
				6,478		
16	Borrowed from Marchlis-bach.					
	For rip-rap.....	8 + 645	8 + 690	2,258	150	3
	In Embankment..	8 + 238	8 + 270	7,561	550	3
	"	8 + 600	8 + 710	14,016	140	3
				23,835		
17	Cut, 8+776 to 8+860.					
	Cross-sections	8 + 785	8 + 850	1,024	10	3
	Embankment.....	8 + 776	8 + 785	458	18	3
	Rip-rap	8 + 810	8 + 870	1,629	20	3
				3,111		
18	Excavation for Rip-rap, 8+780 to 8+870.					
	Embankment.....	8 + 600	8 + 710	1,516	165	3
				1,516		

No.	Description.	Location from Stat.	Location to Stat.	Cubic Meters in Place.	Length of Haul.	Percentage of Increase.
19	Cut. 8+950 to 9+150.					
	In cross-sections..	8 + 950	9 + 150	8,267	20	3
	In embankment ..	9 + 025	9 + 035	250	20	3
	"	9 + 100	9 + 140	2,171	40	3
				10,688		
20	Cut, 9+220 to 9+500.					
	In cross-sections..	9 + 382	9 + 501	2,342	15	3
	In embankment ..	9 + 382	9 + 598	609	38	3
	"	9 + 150	9 + 225	6,790	96	3
	"	8 + 970	9 + 025	6,893	300	3
	"	8 + 890	8 + 970	17,400	405	3
				34,034		
21	Excavation for Riprap.					
	Embankment.....	9 + 382	9 + 598	326	15	3
				326		
22	Cut, 9+596 to 9+622.					
	Embankment.....	9 + 382	9 + 598	179	16	3
				179		
23	Improvement of Gorner-bach.					
	To be used in improvement itself.	.....	.....	172	5	3
	Embankment....	9 + 642	9 + 646	243	42	3
	"	9 + 382	9 + 598	4,136	151	3
				4,551		

The embankments have to be filled as follows:

Description.	Location		Cubic Meters in		Length of Haul.	Perc'nt'ge of Increase.
	from Stat.	to Stat.	Place.	Fill.		
Embankment, 7+760 to 7+890.						
From cross-sections.	7+760	7+780	142	153	10	8
" " "	7+765	7+820	216	222	10	3
From excavation for culvert and correction of creek	7+	800	555	572	15	3
" "	7+	877	140	151	10	8
" "	7+	877	218	224	10	3
From cut	7+850	7+952	1,900	2,052	80	8
" "	8+850	7+952	2,067	2,130	80	3
				5 504		
Rip-rap, 8+190 to 8+300.						
From cut	8+330	8+350	888	965	55	8
" "	8+310	8+330	762	823	100	8
" "	8+050	8+160	3,308	3,573	90	8
				5,361		
Embankment, 8+160 to 8+320.						
From excavation for rip-rap	8+370	8+495	1,778	1,831	.....	3
From cut.....	8+120	8+175	1.112	1,145	.....	3
" "	7+950	8+110	5,394	5,556	.....	3
" "	7+950	8+050	2,876	3,106	.....	8
" "	8+275	8+335	431	444	.....	3
" "	8+350	8+380	497	512	.....	3
" talus of creek.	8+	400	983	1,012	.....	3
" excavation for rip-rap	8+170	8+300	838	863	.....	3
Borrowed from Marchlis-bach	.....	.....	7,561	7,786	.....	3
				22 255		
Embankment, 8+350 to 8+490.						
From talus of creek.	8+360	8+500	9,017	9,296	40	3
" cross-sections.	8+355	8+465	500	515	10	3
				9.811		

Description.	Location.		Cubic Meters in		Length of Haul.	Perc'nt'ge of Increase.
	from Stat.	to Stat.	Place.	Fill.		
Rip-rap, 8+580 to 8+690.						
From improvement of Marchlis-bach..	.....	.....	1,769	1,822	120	3
From cut.....	8+470	8+570	4,169	4,502	90	8
Borrowed from Marchlis-bach...	.....	.....	2,258	2,328	115	3
				3,428		
Embankment, 8+565 to 8+750.						
From cross-sections	8+720	8+750	213	219	15	3
From excavation for rip-rap	8+780	8+870	1,516	1,561	165	3
From excavation for culvert	.....	.....	571	598	45	3
From cross-sections	8+585	8+650	600	618	15	3
From excavation for rip-rap	8+580	8+690	1,691	1,742	35	3
Borrowed from Marchlis-bach....	.....	.....	14,016	14,436	140	3
				19,174		
Embankment, 8+777 to 9+234.						
From cross-sections	8+785	8+850	1,024	1,066	10	3
" cut.....	8+785	8+802	458	472	18	3
" cross-sections	8+950	9+150	8,267	8,522	20	3
" " "	9+054	9+114	2,171	2,236	40	3
" cut.....	9+020	9+050	250	258	10	3
" "	9+220	9+285	6,790	7,000	96	3
" foundation of culvert	8+970		478	478	0	0
From cut.....	9+285	9+315	6,893	7,100	300	3
" "	9+315	9+380	17,400	17,922	405	3
Improvement of Marchlis-bach....	.....	.....	3 012	3,105	110	3
				48,159		

Description.	Location		Cubic Meters in		Length of Haul.	Perc'nt'ge of Increase.
	from Stat.	to Stat.	Place.	Fill.		
Embankment, 9+382 to 9+598.						
From cut.....	10+118	10+480	451	465	871	3
" "	9+596	9+622	179	185	16	3
" "	9+222	9+051	609	627	38	3
From excavation for culvert	10+	360	479	493	836	3
" " "	9+	450	686	707	24	3
From improvement Gornern-bach....	9+	645	4,136	4,260	151	3
From excavation for rip-rap	....	.....	326	336	15	3
From cross-sections	9+382	9+501	2,342	2,412	15	3
" tunnel	.....	....	11,943	12 981	1,586	8
" cut	9+785	10+015	2,623	2,702	437	3
				25,168		
Improvement of Gornern-bach, 9+648.						
From improvements directly	.....	.....	172	177	5	3
				177		
Embankment, 9+624 to 9+646.						
From correction of Gorner-bach	.....	.....	243	251	42	3
Excavation for culvert.....	9+	645	358	369	12	3
				620		

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XX.

VOLUME II.—MAY, 1885.

[SUPPLEMENTAL.]

MEASUREMENT AND FLOW OF WATER IN DITCHES.

By AUG. J. BOWIE, JR., M. Tech. Soc.

Read May 1, 1885.

At the June meeting, 1884, of this Society, the writer read a paper on the "Measurement and Flow of Water in Ditches." The determination of the miner's inch was given, a few remarks on the flow of water in open channels were made, and finally the application of the formula $Q = a\,c\sqrt{rs}$ to ditches in California, was exemplified. The paper was accompanied by illustrations which showed the several cross-sections of the ditches referred to, supplying detail not otherwise mentioned in the text. A generalization of the facts fixed the values of the coëfficient c, applied to ditches here in operation, to be within the limits of 31 to 45.

In the above equation, the quantities a, r and s, being respectively the area, hydraulic mean depth and slope, were obtained by observation in the usual way. The quantity of water delivered in a second, represented by Q, was ascertained by careful gaugings of the respective ditches. The coëfficient c is thus the

only unknown quantity in the equation, and its value results by ordinary algebraic methods.

The solution appears to be perfectly plain and conclusive, yet the correctness of the calculation has been called in question by Chas. E. Emery, Ph. D., in the April number of Van Nostrand's Engineering Magazine.

Mr. Emery says that there is an "error in the original paper," and gives a " corrected basis," changing the coëfficients.

" *The final formula, instead of being*

$$Q = 31 \text{ to } 45\ a\sqrt{rs},$$

should be for ditches

$$\text{"}\ Q = 109 \text{ to } 116.5\ a\sqrt{rs},$$

and the coëfficient be increased to 180 for board flumes."

The occasion for these comments seems to arise from a reprint of the original paper in the January number (1885) of Van Nostrand's Engineering Magazine, which omitted the illustrations showing the dimensions, these details not being given in the text.

In the formula given

Q — is the quantity of water which the ditch is capable of carrying, in cubic feet, per second.

a — the effective area of cross-section of ditch as constructed originally, in square feet.

r — the hydraulic mean depth in feet.

s — the fall of surface in a unit of length.

c — a coëfficient covering all common losses.

The criticism states that " *an examination of the examples given shows that* the writer *has used in the calculation the 'average depth' of the stream, not the 'hydraulic mean depth,' as stated in the description of the notation."*

This statement is a mistake. On the contrary, the hydraulic mean depth was properly determined, and used in every case.

A comment on the expression, "hydraulic mean depth in feet," to the effect that the word "feet" is unnecessary, was also made. Whether the word "feet" is really necessary or not, it is unquestionably true that the unit of the hydraulic mean depth is

the foot, inasmuch as it results from dividing an area by a line. The quotient must necessarily be a line, and when the other dimensions are expressed in feet, this must also be expressed in feet.

"By assuming probable proportions for the ditches," Mr. Emery finds the value of c for the Texas Creek Branch Ditch to be 109 instead of 33 as given in the original paper; for the Texas Creek Flume, 180 instead of 59; and for the La Grange Ditch, 116.5 instead of 52.

The writer has no means of knowing what proportions in ditches appear probable to any other person, but it appears to him to be obvious that if a hundred engineers were separately assigned the duty of assuming probable proportions of ditches, capable of carrying a given quantity of water in a second, under conditions more or less unfamiliar, that the results would be a great variety of proportions, each giving a different value of the hydraulic mean depth, and consequently a different value of c.

In order to show the unsatisfactory and dangerous nature of this process of reasoning without facts, assume Mr. Emery's coëfficient of 109 for the Texas Creek Branch Ditch to be correct, and deduce from the equation the proportions which Mr. Emery's "probable form of ditch" must have. The Texas Creek Branch Ditch has a stated area of 13.5 sq. ft., a slope of 20 ft. to the mile, running when full 32.8 cu. ft. of water. If the coëfficient c equals 109, what must be its hydraulic mean depth? There results as follows:

$$Q = a\,c\,\sqrt{rs}. \quad \text{Therefore } Q^2 = a^2\,c^2\,rs \text{ and}$$

$$r = \frac{Q^2}{a^2\,c^2\,s}$$

Substituting the values given above, the hydraulic mean depth $r = 0.1312$. Hence the wetted perimeter $\frac{a}{r} = 102.8$ ft. Therefore the cross section corresponding to this wetted perimeter, and area of 13.5 ft. would approximate 102.8 ft. in width, and $\frac{13}{100}$ of a foot in depth, or a width of $\frac{26}{100}$ of a foot, and a depth of 51.3 ft.

This is clearly a *reductio ad absurdum*, but it inevitably fol-

lows if the coëfficient c equals 109, and is applied to the data given in the original paper.

The hydraulic *m. d.* of the Texas Creek Branch Ditch is 1.41 ft.; of the La Grange Ditch* 1.77 ft.; of the North Bloomfield Main Ditch, 1.86 ft.; of the Milton Ditch, 1.72 ft. These elements were used, *not "the average depth,"* as charged by Mr. Emery.

With these data it is a simple matter for any person to solve the equation with reference to c, and thereby determine for himself the values of this coëfficient, which will be found to be respectively 33, 59, 52, as originally stated, and the final formula $Q = 31$ to $45\ a\sqrt{rs}$, to be correct.

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*Amount of water delivered by gauge measurements at Patricksville Junction, 56.5 cubic ft. per second.

Errata in original paper (Vol. I, Transactions Tech, Soc. P. C.):

Page 52, paragraph 2, 1st line, 12th word read *relic* instead of *relict.*

Page 52, paragraph 4, 9th line, last two words read 1″, 1½″ instead of 1′, 1½′

Page 52, paragraph 4, 10th line, 1st word read 2″ instead of 2′.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II.—MAY, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

May 1, 1885.

Vice-President Specht in the Chair.

Minutes of preceding meeting read and approved.

The following propositions for membership were made:

R. M. Catlin, Tuscarora, Nevada, proposed by E. C. Burr, H. C. Behr and Geo. J. Specht.

W. F. Boardman, proposed by L. L. Robinson, Charles G. Yale and George J. Specht.

Wm. C. Belcher (Associate), proposed by L. L. Robinson, George J. Specht and Charles G. Yale.

George J. Specht read a paper, "Notes on Earthwork."

Aug. J. Bowie, Jr., read a supplemental paper on "Measurement and Flow of Water in Ditches."

Mr. Fr. Gutzkow made a verbal communication on the subject of the method of preparing lemon juice for the market.

Mr. Gutzkow said that, "having been informed that sooner or later our farmers in Southern California would desire to know of a practicable way to prepare lemon juice for the market, he had given the matter some attention and was able to present a cheap and reliable method to achieve the purpose. It consists in boiling the juice in a copper kettle to a certain strength, as indicated by a spindle, and to pour the still hot solution on a layer of carbonate of lime or hydrate of lime spread on the floor. After mixing, like making ordinary mortar, the mixture, after twenty-four hours or less, becomes perfectly dry, and can at once be filled in barrels. The effervescence of carbonic gas, when the carbonate of lime has been used, or the heat generated when the hydrate of lime is employed, cause the evaporation of the water which remained in the concentrated juice. The proportions employed are approximately as follows: 120,000 lemons furnish 1,000 gallons of juice which are boiled into 100 gallons. This is mixed with 560 pounds of powdered chalk or 313 pounds of lime, previously slaked in about 100 gallons of water, and yields in either case 1,000 pounds of the salable citrate of lime which will contain between forty and fifty per cent. of citric acid.

"As there exist on this coast no chemical works where the citrate could be worked into citric acid, the product would have to be shipped to England. I am not yet able to give a reliable figure of the price which it would bring before shipment—probably somewhere between five and ten cents a pound. Respecting the choice between lime and chalk as absorbent, I can only state that the former would be cheaper for us and the latter more acceptable to the manufacturer. Compared with concentrated juice, which is the usual form of shipment from Italy, the citrate of lime will be greatly preferable, because in the further manipulations for making citric acid the juice has to be converted into citrate of lime anyhow, and because the citrate does not admit of any adulteration. Owing to the frequent adulteration of the juice with sulphuric acid, the amount of which cannot be determined by a plain assay, and to the fact that the juice arrives frequently in full fermentation, the English manufacturers have tried repeatedly to induce the Sicilian farmers to ship the juice as a citrate of lime. But the usual method re-

quires a steam-boiler and some chemical knowledge. Besides, the citrate of lime obtained by the old way is difficult to dry, and when wet decomposes as easily as the juice itself.

"Citric acid is used in calico printing and for medical purposes, and sold in this market at about 75 cents a pound. If cheaper, it could be used with much advantage instead of bitartrate of potash in baking powders. To set the carbonic acid free from one pound of bicarbonate of soda, 2.24 pounds of cream of tartar are required, and only .83 pounds of citric acid.

"According to the 'Reports of the U. S. Consuls' for 1882, the values of shipments from the single port of Messina in Italy were in 1882:

"Lemons and oranges	$1,765,000
"Essential oil	1,387,000
"Concentrated juice	496,516
	$3,648,516"

The following amendment to Article I, Section 2 of the By-Laws was adopted:

To omit the words "at 7.30 P.M. from September 1st to May 1st, and at 8 P.M. during the remainder of the year," and substitute the words "at 8 P.M."

The following proposed amendments were offered by Mr. Specht:

Amendments to Article II of the By-Laws:

1. To change the beginning of Section 1, as follows:

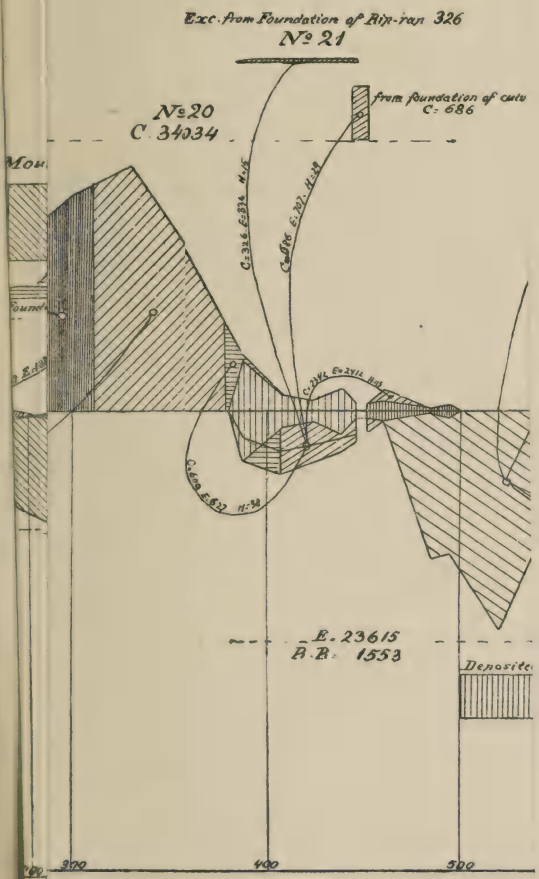
Section 1. "The officers of the Society shall be elected at the annual meeting by ballot, which may be cast in person or be sent by mail, inclosed." * * * *

2. To change Section 2 after the words "at the annual election meeting" at the end of the second sentence of this section, as follows: "At the regular meeting in Jauuary, two judges of election shall be appointed, whose duties are to guard the ballot-box while voting is proceeding, and to count the votes cast after

the President has opened the ballot-box. The ballot shall commence one hour before the opening of the annual meeting, and close twenty minutes after the meeting has been opened. The ballots sent by mail shall be deposited by the Secretary in the ballot-box. The closing of the ballot-box shall be announced by the President, and he shall then open the same. The judges shall then count the votes cast for each candidate and report the result to the President, who announces the names of the elected members to the meeting. The candidate who shall receive a plurality of votes cast for the office for which he had been nominated, shall be declared duly elected." * * * * *

Amendment to Article V, Section 1:

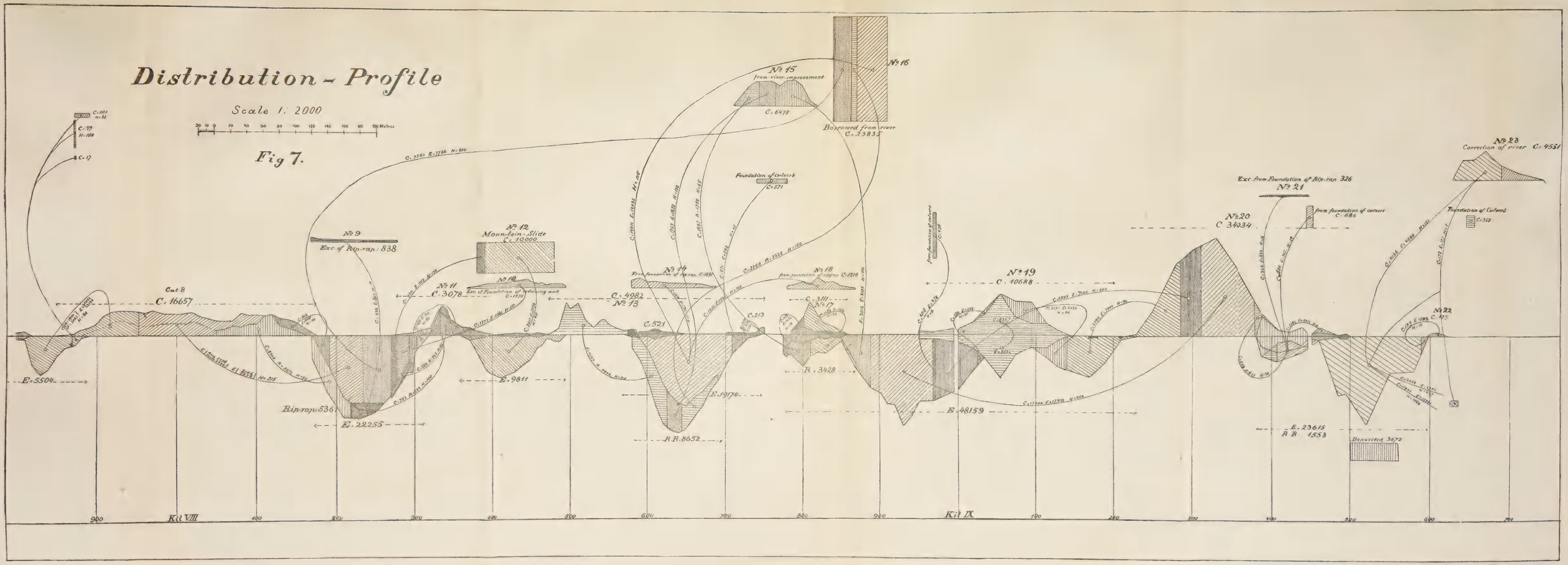
To omit the word "shall" after the words "the Executive Business Committee," and to insert the following words: "may at its own option appoint." To change the name "Executive Business Committee" to "Executive Committee," wherever it occurs in the Constitution and By-Laws.


Exc. from Foundation of Rin-ran 326
No 21
from foundation of cuts
C. 686
No 20
C. 34034
E. 23615
B.B. 1553
Deposite
300
400
500

Distribution - Profile

Scale 1: 2000

Fig 7.



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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XXI.

VOLUME II — JUNE, 1885.

SHRINKAGE OF EARTHWORK.

By P. J. FLYNN, M. Tech. Soc.

Read June 5, 1885.

Some years since experiments were made in Dharwar, in India, by Mr. J. H. E. Hart, C. E., on the shrinkage of earthwork, and the results of these experiments agree with the results arrived at by Mr. Specht (Transactions Technical Society, May, 1885,) namely, that the embankment, at first, gave a volume larger than that of the pit from which the material with which it was constructed was excavated.

Mr. Hart had three pits excavated, and the material from each pit was formed into a bank. The first pit, in black cotton soil, was $49' \times 4\frac{1}{4}' \times 2' = 416$ cubic feet. This was formed into an embankment which measured $50' \times 6' \times \times 2' = 600$ cubic feet. After the bank was measured some of the earth from it was filled back into the pit, up to the level of its edge, and the balance remaining measured and found to be equal to 191 cubic feet. We have here:—First. An increase from pit to bank of 184 cubic feet; and second, again an increase from bank to pit of 7 cubic feet.

During the rainy season (and the rains in Dharwar are heavy), as the material in the pit sank it was filled up to the level of its edge, and at the end of the rainy season the balance was meas-

ured and found to be reduced to 22.5 cubic feet. This showed an increase of the made ground over the pit by 5.3 per cent. The second and third experiments were made in red gravelly soil, or moorum, which is an iron-stone gravel, mixed with about 50 per cent. of earth.

In the second experiment a pit $49\frac{1}{2}' \times 4\frac{1}{4}' \times 2' = 420$ cubic feet, formed a bank which measured $49\frac{1}{2}' \times 6' \times 1\frac{3}{4}' = 520$ cubic feet, giving a first increase of 24 per cent.

A third pit, $49\frac{1}{2}' \times 4\frac{1}{2}' \times 2' = 445$ cubic feet, was excavated, and the material again filled back into pit, leaving a balance of 111 cubic feet=25 per cent., as a first increase. During the rains the pit was kept filled to level of edge, and after the rains the balance was 55 cubic feet, giving an increase of $12\frac{1}{2}$ per cent.

Although these experiments are on a small scale, still they are of some use as information on a branch of engineering that has not been experimented on as fully as the subject requires. The experiments, however, would be more useful were full information given as to how the embankments were constructed and the pits filled, that is, as to whether wheelbarrows or baskets were used for the carriage of the material, and the earth deposited in layers and rammed; or as to whether the earth was simply thrown out from the pit and thrown back again after measurement in bank.

From the large increase of embankment over the excavation, the inference to be drawn is that the material was not rammed.

Embankments in India are often constructed by basket work, the material being carried in saucer shaped wicker baskets, containing less than a cubic foot. In the construction of embankments to retain water this basket work is done in thin layers of less than nine inches in depth, the earth being roughly leveled up as it is deposited from the baskets, and then well punned with wooden or cast-iron rammers weighing about 12 pounds. In addition, the constant trampling of the men, women and children employed in carrying the baskets so consolidates the bank as to make it impervious to water. The layers of earth are sometimes watered. Embankments constructed in this manner shrink or settle very little after they are finished. They are,

in fact, an approach to puddle work, though not nearly so expensive.

The writer has constructed embankments with a grading machine, tipping from wagons from grade, wheelbarrows, hand-cars, carts, scrapers, and punned basket work, and of all these he believes that punned basket work settles the least, and is the best suited for hydraulic work, and the next best work to it for a similar purpose is that done by scrapers.

Thousands of embankments, and some of them counted amongst the largest and oldest dams in the world, have been constructed in India by basket work, without any puddle wall or puddle lining; and some of them, that have been looked after and kept in repair, are as good, if not better, at the present day than when they were originally constructed, hundreds of years since.

This kind of work is done much cheaper there than earthwork in this country. The writer has constructed embankments in the Panjab, the lead being from 100 to 200 feet, for three rupees per thousand cubic feet, that is, at the rate of four cents per cubic yard.

More than forty-five years since Mr. Ellwood Morris, C. E., made some experiments, on a large scale, on the shrinkage of earthwork. The embankments were formed in layers by carts and scrapers, and one winter intervened between the commencement and completion of the work. The results of the measurements are given in the following table:

Nature of Soil.	Excavation Cubic Yards.	Embankm'nt Cubic Yards.	Compression.	
			In Cubic Y'ds	Proportional
Yellow clayey soil.....	6,970	6,262	708	0.1015
" " "	25,975	23,571	2,404	0.0925
Light sandy soil.....	10,701	9,317	1,384	0.1293
On the whole.....	43,646	39,150	4,496	0.1030

The total average compression in embankment being a little more than ten per cent. of the excavation. Other observations, on a smaller scale, showed that gravelly earth shrank about one-twelfth.

The results of these experiments, along with the experiments on rock, are given in the table at page 183.

With a few exceptions, the results of these experiments have been heretofore used, and are still in use to the present day, in American, English, and Indian engineering practice.

As a rule, books of reference in the English language give the shrinkage of different materials, without making any allowance on account of different methods of construction and different heights of bank. For instance, the shrinkage of earth in general is given at about 10 per cent. Now, if 10 per cent. be sufficient for the shrinkage of a bank of that material, and 30 feet in height, constructed from the end of bank to the full height by "tipping" from wagons, surely a similar bank only 12 feet high, built up in layers, and consolidated by good scraper work, will shrink much less than 10 per cent.

In no other branch of Civil Engineering, since the time when railroads were first commenced, has such an immense quantity of work been carried out, and expenditure incurred, as in earthworks; and in no other branch of engineering, of equal importance, have so few experiments, on a scale adequate to the interests involved, been published. In other branches of engineering, long, tedious and expensive experiments are carried out without any other return resulting from them than the information they give; but experiments on earthwork could be carried out on a large scale, as actual work, and with little, if any, additional expense more than the contract price of the work.

In the experiments that have been made there is a want of general agreement, and in some cases the results obtained, in similar materials, differ so much from each other as to point more to errors made by some of the observers than to errors resulting merely from the different methods of construction. This is well illustrated in the table which I now give, showing the percentage of increase or diminution from cut to fill. Some of the materials are mentioned more than once, with a slight change in name, but I deem it better to give the author's own words descriptive of the material than to make a selection of the materials under a fewer number of names.

MATERIAL.	AUTHORITY.	Perc'nt'ge of Increase + or Diminution — of Emb'nkme't to Exc'v'tion	REMARKS.
Sand	Hewson	—10	
Very light sand	Graeff	—10	
Sandy soil	Henz	+ 1 to + 1.5	
Sandy loam	Specht	+ 9	After fill is finished.
Light sandy earth	Morris,	—12.5	
Light sandy soil	Molesworth	—11	
Gravel and sand	Vose	—9	
Sand and gravel	Trautwine—Searle	—8	
Earth	Miss. Levees, 1882		1-5 addition to height of bank
Earth	Simms	—10	
Earth (scraper work)	Canadian Pacific R. R.		Shrinkage of bank 10 %.
Earth (grading machine)	Canadian Pacific R. R.		Shrinkage of bank 15 to 17 %.
Earth (carefully tamped)	Graeff	—9 to —20	
Loam & light sandy earth	Vose	—12	
Loam	Trautwine—Searle	—12	
Clay and loam	Von Kaven	+ 2	After fill is finished.
Clay and light soil	Henz	+ 3	
Clay and earth	Vose	—10	
Yellow clayey earth	Morris	—10	
Gravelly earth	Morris	—8.5	
Gravel	Molesworth—Vose	—8	
Clay	Hewson		1-6 addition to height of bank
Clay	Trautwine—Searle	—10	
Marl	Henz	+ 4 to + 5	
Hard clay	Von Kaven	+ 5	After fill is finished.
Hard clay	Henz	+ 6 to + 7	
Clay before subsidence	Molesworth	+ 20	
Clay after subsidence	Molesworth	—8	
Puddled clay	Trautwine	—25	
Wet soil	Searle	—15	
Loose vegetable surf. soil	Trautwine	—15	
Chalk	Molesworth	+ 30	
Soft sandstone	Von Kaven	+ 3	After fill is finished.
Rock	Von Kaven	+ 8 to + 10	After fill is finished.
Rock	Henz	+ 8 to + 12	
Rock	Vose	+ 50	
Rock	Graeff	+ 50 to + 60	
Rock	Rhine Nahe Railroad	+ 25	
Rock	Trautwine	+ 66 to + 75	
Rock, large fragments	Searle	+ 60	
Hard sandstone rock, large fragments	Morris	+ 42	
Blue slate rock, small fragments	Morris	+ 60	
Rock, large blocks	Molesworth	+ 50	
Rock, medium fragments	Searle	+ 70	
Rock, medium unselected	Molesworth	+ 25 to + 30	
Rock (metal)	Molesworth	+ 20	
Rock, small fragments	Searle	+ 80	
Rock fragments (loose heap)	Trautwine	+ 90	
Rock fragments (carelessly piled)	Trautwine	+ 75	
Rock fragments (carefully piled)	Trautwine	+ 60	
Rock mixed ⅓ to ½ clay	Von Kaven	+ 9	
Rock with considerable clay	Graeff	0	

The experiments of Henz, Von Kaven and Graeff, given above, are taken from Mr. Specht's paper, already referred to. The experiments of Henz, quoted in the above table, are stated to give the *permanent increase* in volume from cut to fill, and to be the result of a *large number of observations* of actual work.

From an inspection of the table it will be seen that Henz gives a permanent *increase* in volume of from 1 to 6 per cent—sand and clays—for materials of the same description as those for which Mr. Morris and other engineers allow a *shrinkage* of from 8.5 to 12.5 per cent.

Then, again, for rock Henz allows an increase of from 8 to 12 per cent., and Von Kaven an increase of from 8 to 10 per cent., but for the same material, Morris allows 42 to 60 per cent., Searle 60 per cent., Trautwine 66 to 75 per cent., and Molesworth 50 per cent., of increase.

The writer is at present engaged on the construction of the south jetty of Oakland harbor for the United States Government. In the carefully laid dry masonry of this work, where all badly fitting stones are rejected for face work, and the stones are too large to be laid by hand and require a derrick for that purpose, the voids, before chinking is done, are more than 12 per cent. of the laid face work. There is no method of railroad construction by which an embankment can be made so as to have as few voids as this jetty. On the contrary, however, by the usual methods of construction, the voids will be found to be from six to seven times more than the quantity given by Henz

The difference in rock between the German, and the American and English experiments is very great, but it will not be difficult to prove that there is something wrong with the German rock experiments. Trautwine gives the average weight of granite at 170 pounds to the cubic foot, and he also gives the weight of a cubic foot of roughly scabbled dry rubble granite masonry at 125 pounds. There is, therefore, an increase in volume of 36 per cent. from solid rock to dry masonry. In order to reduce the increase to only 8 per cent., given by Henz, the voids in his rock embankment would have to be less than one fourth of that of the dry granite masonry mentioned. In railroad construction, as generally carried out, this is not possible.

Well dressed granite or limestone uncoursed masonry contains more than 8 per cent. of mortar. General Gilmore, in his work on *Limes, Cements, etc.*, states that ordinary masonry, in *courses* of 12 in. to 20 in. rise, contains about 8 per cent. of mortar.

If the percentage of increase allowed for rock is to be accepted as a fair sample of the accuracy of the experiments of Henz and Von Kaven, as a whole, then the conclusion to be arrived at is, that any estimates based on them must be inaccurate and lead to serious errors.

The disagreement of the German authors from the American and English authors as to shrinkage is certainly remarkable. The Germans give, on the whole, a permanent increase for sands, clays, and similar materials; but, on the contrary, the Americans and English give a diminution. For rock the latter give an increase from cut to fill many times more—in some cases nine times more—than the former.

American and English authorities also differ materially on some points, as shown in the small table below, which gives the percentage of increase for rock of different sizes:

	MOLESWORTH.	SEARLE.	TRAUTWINE.
Rock, large fragments.....	+ 50	+ 60	+ 66 to + 75
Rock, medium fragments..	+ 25 to + 30	+ 70	.....
Rock, small fragments....	+ 20	+ 80	+ 60 to + 90

In this table it will be seen that Molesworth makes the voids to decrease with the decrease in the size of rock, whereas Searle and Trautwine make the voids to increase with the decrease in size of the rock.

Under the heading of *Volume of interstices in Concrete*, Molesworth gives, for five descriptions of small stone, the "percentage of total"—that is, the percentage of interstices to total volume. The mean of these five is 44. In a volume of 100, including voids, the voids therefore amount to 44, which is equivalent to an increase in volume of 79 per cent. from the solid rock. This agrees with Searle and Trautwine.

In Gillespie's *Roads and Railroads*, he gives a quotation from Gayffier, which says:

"A cubic metre of broken stones, placed in a water-tight box, "which they just fill, can receive in the empty spaces between "the fragments a volume of water $\frac{48}{100}$, or nearly one-half of the "whole, the actual solidity of the stones being therefore only "$\frac{52}{100}$. This does not vary for stones from 1 to 8 inches in "size."

This is equivalent to an increase of 92 per cent., and is practically a close agreement to the result obtained by Trautwine, with a loose heap of rock fragments, which gave an increase of 90 per cent.

As an instance of large percentage for shrinkage, I may mention the construction of the Western Division of the Canadian Pacific Railway, where 10 per cent. was allowed for the subsidence of earthen embankments constructed by scraper work, and 15 to 17 per cent. for similar banks constructed with a grading machine.

Another instance of still larger percentage is that on the construction of the levees of the Mississippi (1882), where 17 per cent. is allowed for shrinkage of *embankment*, and this, be it remembered, is for an embankment which is intended to keep out water. The specifications do not state the method of construction, and no mention is made of a grading machine, but it is stated that, "a sufficient number of dumping men be kept on "the levee to spread the earth as it is wheeled or carted in."

In sandy loam Mr. Specht found the volume of embankment, after completion, to increase more than 9 per cent. over the excavation. Morris and other authorities found that similar materials had an ultimate shrinkage of over 10 per cent. Therefore, to cause an equal shrinkage of 10 per cent. from cut to fill in Mr. Specht's work, his *embankment*, after completion, would have to shrink about 18 per cent. In other words, a bank of loam ten feet high, built up in layers, by scraper work, would have to settle about two feet.

An examination of the table at page 183 will show other serious differences amongst the authorities given, in the percentage allowed for shrinkage.

In such experiments any near agreement is not to be expected, but at least it is reasonable to expect a general agreement tending one way from the same materials in similar banks. The

experiments conducted in this manner should all show, for similar materials, either a diminution or increase, and not a diminution in one case and an increase in the other.

In the practice of American and English engineers there is considerable divergence amongst themselves as to the *subsidence* or settlement of embankments, which *subsidence* again depends on their shrinkage in volume. Some authors give the percentage of shrinkage without any reference to settlement of bank, and in these cases the inference to be drawn is that the settlement is the same as the shrinkage. Other authors give rules for the settlement which do not agree with the shrinkage.

In order to show the want of accord in the rules given, I give three examples from three well known authors. Searle, in his *Field Engineering*, gives the ratio of shrinkage to cut for different materials, and adds with reference to settlement:

"The lineal *settlement* will be about in the ratios given above."

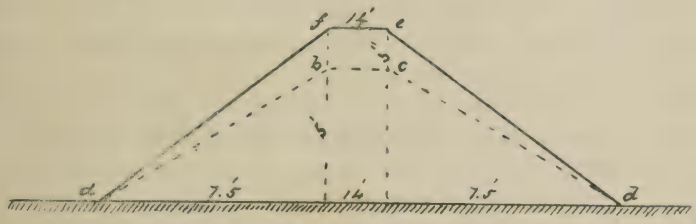
An investigation will show this rule to be correct.

Alexander L. Holley, C. E., in his *Railway Practice*, states:

"The shrinkage of earthwork is stated to be as the cube of "the depth; hence the necessity of due provision in lofty banks."

For the purpose of illustration, the shrinkage and settlement are assumed for a bank 5 feet high, and from this the settlement of a bank 40 feet high is found. The bank shown in fig 1 (not to scale) is 14 feet wide on top, 5 feet deep, and has side slopes $1\frac{1}{2}$ to 1.

Fig. 1.



(NOT TO SCALE.)

After ultimate shrinkage the five foot bank is assumed to have settled 3 inches; therefore the area of shrinkage will be a, b, c, d, e, f, a, on fig.; equal to $21.5 \times .25 = 5.375$ square feet,

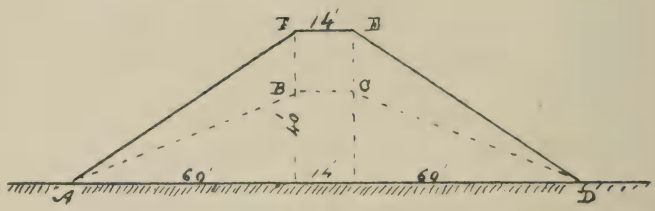
which is a reasonable shrinkage, being only 5 per cent of the area of the bank.

Now as $40^3 : 5^3 :: 512 : 1$.

Therefore the shrinkage of the 40 feet bank will be:

$5.375 \times 512 = 2752$ square feet. This is equal to A, B, C, D, E, F, A, fig. 2; and as the shrinkage is all vertical, the area of shrinkage divided by mean width=settlement.

Fig. 2.



(NOT TO SCALE.)

Therefore the settlement $= \frac{2752}{74} = 37$ feet, being almost the full height of bank.

If the shrinkage of the 5 feet bank be taken at only 2 per cent., then, by the rule of the cube of the depth the settlement of the 40 feet bank will be 14 feet. From these examples it will be seen that this rule does not hold good, and that the shrinkage is not as the cube of the depth. Mr. Holley evidently copied this rule without investigation.

There is a sort of scientific look about the rule, but an investigation will show that it is nothing more than a most useless and misleading rule of thumb.

To show how rules are sometimes glanced over and accepted without investigation, it may be mentioned that this rule was given, several years since, in a work which, in other respects, is accurate, namely, the Treatise on Civil Engineering in use at the Roorkee Civil Engineering College, and, in all likelihood, it is continued in it to the present day in the last edition. It was not until long after the writer left the college that he tested its accuracy and found out its fallacy.

Vose, in his *Manual for Railroad Engineers*, quotes the exper-

iments of Morris for shrinkage, after which, and under the heading of *subsidence*, he states:

"It has in some cases been specified that the embankments, "when completed by the contractor, should be finished to the "full height from three inches above the intended height, upon "a bank 5 feet high, to nine inches upon a 40 foot bank; and "intermediate heights being in proportion."

Vose here gives a rule that in a certain case, when a 5 feet bank subsides 3 inches a 40 feet bank will subside 9 inches. He also states that banks shrink a certain percentage *in proportion to their volume.* As already shown at page 188, the shrinkage of a 5 foot bank, and corresponding to a subsidence of 3 inches, is 5.375 square feet, which is five per cent. of the area of bank 107.5 square feet.

Now, a 40 foot bank (fig. 2) has an area of 2960 square feet, and 5 per cent. of this=148 square feet=its shrinkage; and as this shrinkage occurs only in the vertical direction, $\frac{148}{74}=2$ feet=the depth of settlement, and not 9 inches. From this it will be seen that the rules for shrinkage and settlement, as given by Vose, do not agree with each other.

I think I have shown that there is a great want of general agreement in the results of experiments on shrinkage, and also in the rules for settlement as given by writers on the subject.

Holley says: "Correct allowance is made for the settling of "the material of the bank, and time is given for this settling to "occur before the ballast is brought on or the rails and sleepers "laid. The shrinkage of earthwork sometimes disturbs the "grade at a rate of several feet rise or fall per mile—in normal "grades of 60 feet, on the New York and Erie road, a distance "of 500 feet was found to rise at the rate of 75.4 feet per mile, "this distance being approached and succeeded by the regular "grade of 60 feet. In another place, for the distance of 200 "feet, the rise was found to be at the rate of 116.7 per mile, "with a level of 100 feet length both above and below—the aver-"age grade over the whole mile being 60 feet. These cases are "similar to what occurs where railway earthwork is not properly "settled before being brought into use."

On the assumption that the settlement is in proportion to the shrinkage in volume, I will now show that even when due allowance for settlement is given to the bank to make up for the shrinkage in volume *from cut to fill*, still cases happen where the bank will settle more than that allowance, and it is possible that the banks mentioned by Mr. Holley had, when they were first built, the full allowance for settlement usually given.

It is well to note here that there is a marked difference, in some cases, between the shrinkage of an *embankment*, and the shrinkage of the material of which it is composed, *from cut to fill.*

Trautwine says: "Although earth, when first dug, and loosely "thrown out, *swells* about $\frac{1}{5}$ part, so that a cubic yard *in place* "averages about $1\frac{1}{5}$ or 1.2 cubic yards when dug; or 1 cubic yard "dug is equal to $\frac{5}{6}$, or to .8333 of a cubic yard in place; yet "when made into an embankment it gradually subsides, settles "or shrinks into a less bulk than it occupied *before being dug.*"

Molesworth, in his Pocket Book, states that clay, before subsidence, increases in volume 20 per cent. from cut to fill, but that after subsidence it shrinks in bank 8 per cent. less than the volume in cut. The *embankment* therefore shrinks from a volume of 120 to a volume of 92. This amounts to a *total shrinkage of embankment* of 23 per cent.

Mr. Specht's experiments support these statements as to the first or temporary increase from cut to fill. He found that "53,350 cubic yards in cut gave 58,350 in fill," in "sandy loam "with small amounts of adobe and hard pan," which is an increase of 9.4 per cent. Mr. Specht remarks with reference to this increase: "This question must not be confounded with "that of final settlement, which sometimes even continues for a "long time after the embankment is finished."

The temporary increase of volume in embankment mentioned below, has reference to banks built up with some rapidity, to full height and without layers.

In the table, page 183, it will be seen that, for materials similar to Mr. Specht's embankment, American and English engineers give a permanent shrinkage from cut to fill of from 8 to 12.5 per cent., being an average about 10 per cent.

This final shrinkage, as well as the first increase, being allowed

it is evident that the *total shrinkage of an embankment from its first completion* to its *permanent settlement*, must equal the *first increase* in bank beyond the volume in cut, plus the *final shrinkage* from cut to fill, that is, in the case just given, $9.4 + 10 = 19.4$ in a volume of 110 which is equivalent to 17.6 per cent.

In order to have a permanent depth of 40 feet after settlement, an embankment in the material just described would require to be built 48.5 feet in depth at first.

If the banks mentioned by Mr. Holley were intended to be, say as an instance, 46 feet high after final settlement, and that the material of which they were constructed increased at first 5 per cent. more than cut, and had a final shrinkage of 10 per cent. less than the cut, then the total shrinkage of 14 per cent. would require the depth at first to be 53.5 feet. If, however, 10 per cent. be allowed only for shrinkage, the bank will at first be 51.1 feet deep, and as the actual settlement of this at 14 per cent. will be 7.2 feet, the bank at final settlement will be only 43.9 feet deep instead of 46 feet, which is 2.1 feet lower than intended. This is as much as the greatest settlement of bank already mentioned by Mr. Holley, and is due entirely to the fact that no increase in depth of bank was allowed in proportion to the first increase in volume from cut to fill.

Is it not probable that a great deal of the settlement noticed in earthen banks is to be accounted for as just explained?

For *balancing* cuts and fills, only the permanent difference of volume in cut and settled bank is to be taken into account, but for settlement of bank an additional allowance has to be made for the temporary increase in volume from cut to fill.

Cases occur where it would not be advisable to allow for the full shrinkage of a bank during construction, and it is here that the element of *time* is of importance. Hewson, in his work on *Levees*, says:

"Sand, however loosely it may be shoveled together, fills its "space closely; and, therefore, whether wet or dry, settles at a "very small diminution of the original bulk. In *time*, too, the "process of this settlement is short."

Spons' Dictionary of Engineering states:

"The ultimate settlement of embankments of gravel or chalk

"does not require more than two or three years, but clay em-
"bankments may, in some cases, continue to shrink for ten
"years."

To give an instance where it would not be advisable to allow for the full shrinkage. Let an embankment, on a maximum or ruling grade of 1 in 100, be built across a hollow, and let its depth gradually increase until at a distance of 200 feet from beginning of fill, its depth is 40 feet. From experience with similar material, it is known that the embankment will shrink about 10 per cent. within two years, of which five per cent. takes place within six months, and another five per cent. within a further period of 18 months. The road is to be in full operation within about six months from construction of the embankment. Now, if an allowance is made in height of bank for ultimate shrinkage of 10 per cent., then its height at greatest depth will be 44.4 feet; but as, within six months, it will shrink only 5 per cent., then its height at that time will be 42.2 feet—that is 2.2 feet higher than grade. This 2.2 feet additional height is gained in 200 feet, and it increases the grade of road from 1 in 100 to a steeper grade than 1 in 50, but as the ruling grade is to be 1 in 100, the allowance for ultimate settlement during the construction of the bank is not admissible. If, however, shrinkage for only 5 per cent. be allowed at first, and the bank built up to 42.1 feet in height, it will, at the end of six months have settled down to 40 feet and be even with the ruling grade. After this, as the bank gradually settles, it can in the regular course of track repairs be brought to grade by the trackmen with additional ballast.

As to the effect of *time* in the consolidation of banks, the writer is of opinion that an embankment, built of loam with a slight admixture of sand, does not after several years so shrink and consolidate as to equal for hydraulic work to a comparatively new bank built in layers of less than one foot thick and rammed. The effect of time does not consolidate the bank so much as punning during construction. This opinion is based upon considerable experience in cutting through banks of the material mentioned.

Very old banks are not here referred to, as the writer has had no experience with them.

In the original construction of that part of the Grand Trunk Road from Lahore to Wuzeerabad, in the Panjab, provision was made for drainage—by bridges and culverts—only at the well-defined drainage channels. After the completion of the embankments, the drainage works were found insufficient to carry off the flood waters, as before the construction of the embankment, more water was passed away over the surface of the country than by the well defined drainage channels. In times of very heavy rainfall the embankment dammed back this water, which rose behind it, flooded the country on the up-stream side of the bank, breached the road, carried away bridges and impeded the traffic.

In the construction of bridges and *metaled gaps* to carry off the flood waters, the writer had to cut through the embankments in more than twenty-four places, making an aggregate length of more than 8,000 feet in a distance of fifty-eight miles.

In places where the bank was built without punning, it was found, that after taking off about two feet in depth of the top, the body of the bank appeared like material newly deposited, and it was easily excavated. On the other hand, the banks which were built in layers and punned, were found to be well consolidated and much more difficult to excavate. The difference in the banks, though built of the same material. was very marked, the punned banks, even when comparatively new, being much more difficult to excavate than the others.

After each rainy season the tops and slopes of the unpunned banks were much more cut up and fissured, and required more repairs than those that were punned.

The banks were forty feet wide on top, with side slopes of two to one and from four to twelve feet high.

In some cases, during floods, the unpunned banks were breached by leakage, before the water reached their tops, but not in a single instance was the punned bank breached by leakage. Where, however, the punned banks were breached, the water first rose above their tops, and in flowing over them and falling to the down stream level, cut through them.

After a bank was constructed, the heavy and continuous traffic passing over it so consolidated its top that it acted as a roof, and passed off the rain-water to the side slopes. The rain-water

was thus prevented from entering the body of the bank and contributing to its shrinkage.

From the experience gained in this work, it is the opinion of the writer that time does not so compact and solidify an old, unrammed bank as to make it equal for the purpose of impounding water to a rammed bank, even when the latter has been built more recently; and it is also his opinion that the top of a bank for impounding water should not be used as a roadway until after the lapse of sufficient time to allow it to take its ultimate shrinkage.

A few words here in explanation of metaled gaps. They are simple, inexpensive road-works, to pass off surface flood waters, and to save bridging.

It was found that the bridging on the Grand Trunk Road required to pass off the flood water, amounted to more than than 8,000 feet in length. The great expense and the length of time required to complete this work prohibited bridging. To provide ample outlets for surface drainage, portions of the embankment varying in length, according to the requirements of the flood-waters, from 100 to 1,700 feet at ground level, were excavated, and from ground level at each end slopes of one in thirty were made to top of bank. The slopes and the portion on level of country were metaled to a width of eighteen feet, and on each side of the metal, a brick wall, two feet deep and one foot wide, was built, the top of the walls being on a level with the metaling. A row of guide-posts 100 feet apart were fixed on each side of the metaling to guide travelers and vehicles to keep on the roadway during floods. During floods, which continue for only a few days in the year, these gaps passed off the surface flood-water at a low depth—less than two feet—and at such a low velocity as to permit traffic to be carried on in safety through the water, though at great trouble and inconvenience.

During floods the gaps were fords, and at other times they made a good metaled road.

After the flood subsided, the ordinary drainage of the country was passed off by the well-defined and deep channels which had bridges or culverts built over them.

This cheap expedient of gaps for passing off surface flood-

water permitted the opening of the road, during the rainy season, several years before it would otherwise have been done, had bridges been built at the time, instead of gaps, for carrying off all the surface flood-water.

I will now show that under certain forms of longitudinal section, and one very likely to occur in broken ground, the use of certain formulæ in the computation is sure to cause a serious error in the result. Gillespie says in his *Roads and Railroads:*

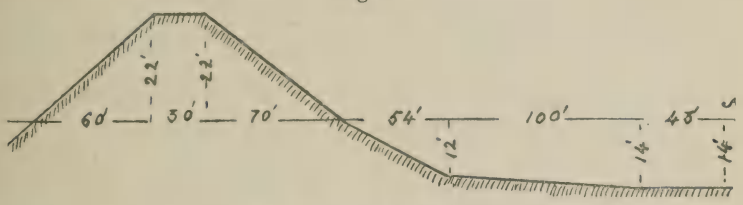
"Average end areas is the most usual method in this country" for computing earthworks.

Morris, in his *Earthworks*, says in reference to same formula:

"This rule has been by far the most used of any in our "country. With tables of cubic yards it is very expeditious, "and has found numerous advocates amongst engineers on ac-"count of its simplicity and convenience."

Searle states that this formula is approved by statute to be used in the public works of the State of New York.

Fig. 3.



LONGITUDINAL SECTION.

The diagram represents the longitudinal section of part of a line of railroad, the ground at all points transversely to the centre line being level, so that all cross-sections will be on level ground.

The cut is 18 feet wide at base, with side slopes 1 to 1, and the fill 14 feet on top, with side slopes $1\frac{1}{2}$ to 1.

In order to make an experiment on shrinkage, the engineer takes out the cut and builds the bank to the sections required. The end of the bank is assumed to stand vertically at A. The quantity in cut completes the embankment for 197.06 feet in length, as shown in diagram. After final measurement, the engineer computes his quantities by the formula of average end

areas. He finds the volume of cut = 3,096 cubic yards, and the fill = 2,784 cubic yards. The quantity in cut appears, therefore, to exceed the fill by 312 cubic yards, showing a shrinkage of 10 per cent. In fact, however, there is no shrinkage. If the computations are made by the *prismoidal formula*, the volume of the cut will be found to be equal to that of the fill, 2,708 cubic yards, so that the apparent shrinkage of 10 per cent. was entirely due to the use of an incorrect formula

If, again, the computation be made by the formula of *average end heights*, in which a section is taken with a height equal to the average of the two end heights, the volume of the cut will be = 2,514 cubic yards, and the fill = 2,670 cubic yards, showing an increase of 156 cubic yards = 6 per cent., which increase does not exist, as the cut and fill exactly balance, as before explained.

The use of the latter formula of mid sections gives a deficiency equal in amount to half the excess found by the use of average end areas.

Another formula by *mean proportionals* which gives less than the correct result, is sometimes used. The prismoidal formula is the only one of the four given which is sure to give correct results.

The error will be even more than shown above, when the ground at cut slopes also across the centre line of road.

The error is greatest when one of the end areas = 0, as seen in the column of cut given below. In similar cross sections, in ground where the end heights do not materially differ, the error is small, as will be seen in column of fill given below. Error in the results, however, can be avoided only in so far as the computations are concerned by the use of the prismoidal formula.

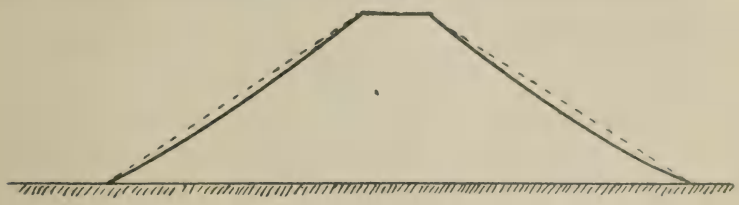
The following table gives the volume of cut and fill by the three formulæ used above:

	Cut Cubic Yards.	Fill Cubic Yards.
Prismoidal formula.....	2,708	2,708
Average end area	3,096	2,784
Average end heights.....	2,514	2,670

There is a tendency among workmen to leave the side slopes

curved in cross section. For instance, embankments are sometimes finished with the side slopes concave, as shown in Fig. 4: and cuttings, especially in hard ground, are left with the side slopes convex, as shown in Fig. 5:

Fig. 4.



It is therefore advisable, in cross-sectioning the work for final measurement, to take levels and measurements at frequent intervals, and before doing this work the adjustment of the level and the length of measuring instruments, chain, tape, etc., should be looked to.

Fig. 5.

In descriptions of *shrinkage* experiments on earthwork, the following information would be useful, and in addition such other information as might be deemed of use in arriving at a correct result:

1. The description of material and locality.

2. Method of construction, such as by scrapers, wheelbarrows, tipping from wagons, etc.

3. Longitudinal section, and also cross-sections of cutting and embankment.

4. Average depth of layers, and if rammed.

5. Foundation of bank, that is, description of ground on which the embankment is constructed.

6. Dates of commencement and completion of bank and of measurement.

7. Rainfall, if any, and a general description of weather during period of work.

8. The formula used in computing the quantities.

9. If base of bank has been flooded, the depth of flooding, period during which flood lasted, and state of bank at the time, should be given.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXII.

VOLUME II.—JUNE, 1885.

GAS FURNACES—GENERATIVE OR RECUPERATIVE.

By J. B. CROCKETT, M. Tech. Soc.

Read June 5, 1885.

By this term we will call any of the many arrangements called generators, by which solid fuel is converted into a gaseous state, of which the main heating constituent is in the form of carbonic oxide (CO); this being led into the base of the bench by proper channels and combined with the proper amount of air, which has also been conducted to the same part of the bench by channels and openings, so as to oxidize or burn the carbonic oxide (CO) to carbonic acid (CO_2) in the arch itself.

If the air so supplied for the combustion of carbonic oxide into carbonic acid has been previously heated by the waste gases passing off from the bench, we are then said to employ "recuperation," from the fact that we take back into the bench a part of the heat which was passing off to the chimney, by heating the air of combustion with it after it leaves the arch or before it reaches the chimney.

So that we may have generator furnaces either with or without recuperation.

It is only when the recuperation is obtained from the exit products of combustion of the bench, that any economy results in

this regard, for if we heat our air by heat transmitted through the walls of the generator or furnace, we are simply robbing our fires of heat before it has done its work, and are forming a system of internal radiation which does not result in economy. On the other hand, when our air is heated by the exit gases, we save a portion of the heat that would otherwise be wasted.

While not attempting to enter into the merits of the different systems of recuperative furnaces in use on the continent, it may perhaps be of interest to give the names of the different inventors, and the places where they are now in use.

The Siemens furnace was first tried at the Horseferry Road works of the London Chartered Gas Company, in 1862, and in 1864 was introduced into the Paris works at Vaugirard, where it was experimented with for some time, and afterwards in a perfected form was put into St. Mandé station in 1869. At Ivry in 1876–8, and at Clinchy in 1880–1. At Paris the consumption of coke was 20 per cent., at Ivry 15 per cent., but the Siemens system required an arrangement of valves which subsequent inventors aimed to do away with.

In 1870 Muller and Eichelbrenner brought out adaptations for heating retorts by gas that had quite an extensive application.

Liegel began his experiments in 1864 at Stralsund, but did nothing with them until 1875, when Mr. Schiele, the manager of the works at Frankfort-on-the-Main, constructed a number of furnaces on this plan and reported very favorable results.

At the South Metropolitan station in London, Mr. Livesy has made some furnaces similar to the Liegel in action.

In 1875 Mr. Oechelhauser also turned his attention to the subject of generator furnaces, and has introduced them very successfully in many places in Germany.

In Munich, Dr. Schilling has also introduced a system of his own, or rather a modification of the recuperative system, and places his amount of coke used to carbonize 100 lbs. of coal at 16 lbs., or 16 per cent.

Generator furnaces are also in use at Cologne, Dresden, Berlin, the Hague, and the gas works at Krupp's immense iron works at Essen.

Now, turning our attention to this country, we find that the

first generator furnace used was patented by Charles Deiterich, engineer of the Baltimore Gas Company, which has been in operation there since June, 1878, and which has given very satisfactory results, but which is considered as being far from perfect, especially in its method of recuperation.

This furnace has been introduced also in Boston and Providence, R. I., but with varying success.

The McIlhenny furnace, patented by George A. McIlhenny, of the Washington Gas Company, has been in operation successfully there for more than a year and a half, and has been adopted by the Chicago Gas Light Company within the past year.

This furnace is essentially a recuperative one, the air being forced by a blower through proper channels over the tops of the benches and thoroughly heated by the waste, or exit heat, before being admitted into the combustion chamber.

In Mr. McIlhenny's first experiments with his furnace, he began to charge each retort with 200 lbs. of coal, but found that he could as easily work off 300 lbs., or 2,400 lbs. in 24 hours to each retort, making 12,000 cubic feet of gas; he then increased his charges to 350 lbs., or 2,800 lbs. in 24 hours, or 14,000 cubic feet of gas to each retort. This, however, he found gave him considerable trouble by pitching the tar in the mains.

There appeared to be no limit to the amount of heat which could be obtained, and it appeared to be as easily controlled as turning on and off the steam to an engine.

In actual practice since the extensive use of his furnace, Mr. McIlhenny now considers that it is better to charge a larger amount of coal per retort, and allow the charge four hours in which to burn off, rather than to force his heat by three-hour charges, which always had a tendency to stop up his hydraulic main and ascension pipes.

As to the practical workings of some of the different methods of regenerative furnaces, I will give some personal notes, taken by me in the year 1884, on the Deiterich furnace.

Twenty benches, of six retorts to the bench, were erected under the personal supervision of the inventor, and no gas was made except by these benches, so it was a fair working experiment. The amount of gas sent out from these benches in

December, 1880, was 29,980,000 cubic feet. The yield per lb. of coal was 4 $\frac{98}{100}$ cubic feet, or 11,144 cubic feet to the ton of coal carbonized.

The highest yield per retort for one day in that month was 9,133 cubic feet, the lowest 7,300 cubic feet, while the average for the month was 8,610 cubic feet.

The highest charge of coal per retort during the month was 229 lbs., the lowest 184 lbs.; the average of all the charges was 202 lbs.

The amount of coke used for firing being about 30 per cent. of all the coke made. Duration of charge, three hours.

A better idea of these results may be had by comparing the regenerative with the old methods of firing:

	Deiterich System.	Old System.
Duration of charge	3 hours	4 hours.
Coal charged	202 lbs.	250 lbs.
Yield per retort	8,610 *c. f.*	5,000 *c. f.*
Yield per lb. coal	4 $\frac{98}{100}$	4.60.
Coke used	30 %	50 %
Cannel used	$2\frac{1}{2}$ %	5 %
Life bench	2 years	2 years.

That the figures as given by Mr. Deiterich are not excessive in regard to the large yield of gas per retort and the small amount of coke used, is shown by the report of Mr. A. B. Slater, of the Providence, R. I., Gas Company, who adopted his system in November, 1880, and after two and a half months' use reported the following results: Charges, 3 hours—average coal charged, $262\frac{1}{2}$ lbs.; average yield per lb., 4 $\frac{82}{100}$ cubic feet; average yield per retort, 9,666 cubic feet; coke used, 22 $\frac{5}{10}$ per cent.

I have given the figures on the Deiterich furnace, not that I consider that the best system of firing by gas, but because I am more familiar with the practical working results of it than the others.

In regard to the economy of these furnaces, there are a great many claims made:

1st. A saving of about 50 per cent. in fuel, when compared with ordinary grate furnaces, using the same kind of coal, having

the same number of retorts, and producing almost double the amount of gas per bench.

2d. Any degree of heat can be obtained. By this the productiveness of the retorts can be increased, as far as the illuminating power of the gas, the quality of the tar, or the material of the furnace will allow.

3d. Greater durability of the furnaces, as the walls and the fused slag do not come in contact.

4th. Automatic cleaning of the fires from slag, by the fusing of the latter, which lessens the labor of the firemen.

5th. Continuous or intermittent firing, as desired, there being no necessity for drawing the fires, even for stoppages of 72 hours' duration, during which time no watching is required.

6th. The decreased amount of enriching material needed to keep the gas up to the proper standard, for most of the reports agree that the gas is richer when generated by these furnaces.

The reason given by Mr. George E. Davis, in his paper before the Society of Chemical Industry is, viz.: "More free hydrogen seems to be formed at the higher temperatures, and this becoming saturated with benzine vapor, robs the tar of its benzine to a certain extent. At lower temperatures less gas is produced and more benzine remains in the tar."

7th. A much smaller outlay is required for the original plant, as one-half the number of retorts can do the same amount of work.

I have considered this subject solely in relation to its uses by gas companies, but you can all recognize the fact that there is a greater and wider field for the regenerative furnaces in rolling mills, glass works, and all other industrial pursuits where a great and easily controlled heat can be applied.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II — JUNE, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

June 5, 1885.

Vice-President Specht in the Chair.

Frank Soulé, Jr., was proposed for membership by Ross E. Browne, Aug. J. Bowie, Jr., and Geo. J. Specht.

Wm. H. Radford and W. F. Boardman were declared duly elected members, R. M. Catlin, a non-resident; and Wm. C. Belcher an associate.

P. J. Flynn read a paper on "Shrinkage of Earthwork."

J. B. Crockett read a paper on "Regenerative and Recuperative Furnaces."

The following amendments were adopted:

Amendments to Article II of the By-Laws.

1. To change the beginning of Section 1, as follows:

SECTION 1. "The officers of the Society shall be elected at the annual meeting by ballot, which may be cast in person or be sent by mail, inclosed." * * * *

2. To change Section 2 after the words, "at the annual election meeting" at the end of second sentence of this section, as follows: "At the regular meeting in January, two judges of election shall be appointed, whose duties are to guard the ballot-box while voting is proceeding, and to count the votes cast. The ballot shall commence one hour before the annual meeting, and close twenty minutes after the meeting has been opened. The ballots sent by mail shall be deposited by the Secretary in the ballot-box. The closing of the ballot-box shall be announced by the President, and he shall then open the same. The judges shall thereon count the votes cast and report the result to the President, who shall then announce to the meeting the names of the officers elected. The candidates who have received a plurality of the votes cast for the respective offices, shall be declared duly elected." * * *

Amendments to Article V, Section 1:

To omit the word "shall" after the words "the Executive Business Committee," and to insert the following words: "may at its own option appoint." To change the name "Executive Business Committee" to "Executive Committee," wherever it occurs in the By-Laws.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXIII.

VOLUME II.—JULY, 1885.

EXPERIMENTS IN PROTECTING TIMBER FROM LIMNORIA AND TEREDO IN THE BAY OF SAN FRANCISCO.

By MARSDEN MANSON, M. Tech. Soc.

Read July 10, 1885.

Before entering into a description of the methods tried in the Bay of San Francisco to protect timber from the ship worm and limnoria, it would probably not be out of place to give a general description of the two pests which necessitate the protection.

THE TEREDO.

The oldest and best known of these is the common ship worm (*Teredo navalis*), a headless mollusk having a nearly cylindrical body, varying when grown from a few inches to thirty-six inches in length, and from one-quarter to three-quarters of an inch in diameter. The body is nearly gelatinous and is traversed by several tubes, serving as an intestinal canal, for transmitting the excavated wood, for introducing water and perhaps air. The principal tubes are two, in the shape of a syphon, entering the posterior end of the body, passing nearly its entire length, and, turning back, passes out again. Near the bend it enlarges into a sack, into which project small hairy absorbing vessels which

supply portions of the materials needed by the animal. Water circulates through these tubes, being apparently drawn in through one and ejected through the other, or up through the space between the body and the walls of the bore and out through the tubes.

The anterior end is encased in a pair of calcareous semi-spheroidal cutters, which are hinged and firmly connected, and operated by a tough, reddish-brown muscle. The posterior end is furnished with a pair of feather-like appendages, which connect with the tubes traversing the body; these feathers apparently serve as claws or spurs to enable the animal to push forward against the wood in front of the cutters.

Specimens of the teredo are presented for your inspection. They were taken from piles driven in 1878 in the Market-street Ferry slips, and removed in 1884. The detached cutters are also exhibited. The teredo attacks across, but prefers to bore in the direction of the grain, enlarging the bore to suit its rapidly increasing size. It usually enters piles a little above the mud, and operates to above low tide. The bore is coated with a thin calcareous lining, secreted by the skin next the cutters. The bore is the same length as the animal, the cutters being at one end and the feather-like spurs at the other. The study of the internal economy of the animal has not been definite enough to determine its exact arrangements, but it appears that the sack or stomach near the bend of the syphon-like tube, before mentioned, supplies the calcareous material for the cutters and calcareous lining, and that the albuminous materials in the sap of the wood supply a portion of the nutrition of the gelatinous body, another portion being probably derived from animalculæ in the water passing through the tubes. It is claimed by many who have investigated the subject that the teredo, like the lithodome, bores only to get a home. This view, however, appears to be somewhat at variance with the appearance and economy of the animal. Nature would hardly pass a nutritive food through the largest tube in the animal's body without utilizing it in some way.

The teredo does not bore into the calcareous lining of another tube. Timber long exposed to the teredo is completely riddled

with holes in all directions, as shown by the specimens of destroyed piles presented. The time necessary for destruction varies very much from several causes, the principal of which are the time of year in which the timber is cut and the purity of the sea water. The first of these regulates the adhesion of the bark, and the second the growth and existence of the teredo germs. Timber with the bark on is not attacked in the Bay; the decay of the cambium generally takes place in from two to three years (even when the timber is cut at the proper season); the bark then falls off. Piles well covered with the bark last generally from five to eight years; in the most exposed localities they have been destroyed in two years; in the least exposed, near the mouths of large sewers carrying waste products from the gas works, they are rarely attacked at all.

LIMNORIA TEREBRANS.

The second pest is a variety of minute shrimp, termed by naturalists the Limnoria Terebrans. There are several varieties. Those found in the Bay of San Francisco are eliptical in outline and vary in length from $\frac{1}{12}$ to $\frac{1}{6}$ of an inch, and in diameter are about $\frac{1}{32}$ of an inch. They are variable in color, from nearly white to dark olive and brown, according to exposure and probably age. They have seven pairs of legs arranged symmetrically on the sides of the body. These legs are provided with minute hooks and claws. The animal can swim, crawl and spring by a quick motion of the body. The eyes are compound and under the microscope vary very much in different individuals. An enlarged microscopic view of one is exhibited; it presents the underside of the animal. The animal is also exhibited preserved in alcohol.

The Limnoria Terebrans was introduced into the bay from other waters; making their first appearance, according to Mr. T. J. Arnold, C. E., at the foot of Battery street. They are now distributed all over the bay. They operate from extreme low to extreme high tide, and eat the softer layers of wood between the rings of annual growth—leaving an unsubstantial mass of friable wood, apparently rotten. Specimens of timber destroyed by the limnoria are presented. They were destroyed in five years;

timber without the bark on is destroyed in about four years. It is, however, possible to periodically destroy the Limnoria by either a poisonous wash, or with a thin batter of cement which will smother them. Either of these applications would require repetition. The extent of damage wrought by these two pests in the bay of San Francisco, cannot be less than $40,000 per year, so that the need of protectives, or even paliatives, is very great.

METHODS.

The methods tried have not been very numerous, and may all be assigned to one of two classes: 1st. Covering the timber with some hard or impenetrable coating; 2d. Impregnating with a poisonous or objectionable substance having antiseptic properties.

THE ROBBINS PROCESS.

In August, 1879, the Robbins Patent Process was tried on both piles and timber used in the construction of the wharf on East street, between Pacific and Jackson streets; also on several other structures on the water front, and by the United States authorities in San Francisco, and at Mare Island; by the Pacific Mail Steamship Company, and by the C. P. R. R. Co. The process belongs to the second class, and is as follows: The barked piles are placed in an iron tank capable of standing considerable pressure. Superheated steam is then introduced into the tank to vaporize and wash out the sap; the wood is then dried by heating and ventillating the tank. The tank is then closed and the vapor of coal tar introduced at considerable pressure and heat. After several hours the heat and pressure are allowed to subside, and the tank to stand closed for ten or twelve hours; the wood is then removed "preserved." So far as known, the results have not been favorable.

In 1870 the piles along the wharf on East street, between Mission and Howard streets, were prepared by this process. This wharf was rebuilt in 1878–9, showing a failure of the process.

About the same time the *Samuel's process* (Class II) was tried on East street near Pacific. This process consists in injecting

into the pores of the wood a solution of sulphate of iron, and precipitating the iron as an oxide with milk of lime, forming also the sulphate of lime. No good results were obtained.

In 1871 the Robbins' process was again tried on East street, on a wharf 550 x 75 feet; the results were again unfavorable.

The Von Jensen Process (*Class II*).—In this process the timber is boiled in dead oil. Only short pieces were put in on Battery street, but the construction of the sea-wall a few years later displaced the samples.

Thilmany Process (*Class II*).—This process consists in exhausting the sap by steam and vacuum, and then injecting under pressure sulphate of zinc or copper and afterwards a solution of chloride of baryta—precipitating sulphate of baryta in the pores of the wood. It was tried upon short pieces of timber sent out from some of the Eastern cities. The samples tried were put in Battery-street Wharf and were removed a few years later, untouched; but similarly prepared timber failed at Fort Point, where the trial was of greater duration.

Horton Process (*Class I*).—This process applies only to piles, and consists in boring a circular groove an inch or more under the bark and extending from the top of the pile to the mud line. This groove or ring is then to be filled with cement or asphaltum mastic; this coating is supposed to act as a barrier to injury to the core. The apparatus used in boring is the same as that used in boring the Wykoff wooden pipe. The process is quite costly, and entirely inapplicable to either long or slightly crooked piles. Three short piles were prepared in 1877 and put in near Battery and Lombard streets. The results are valueless, as the process is impracticable except in very shoal water.

Wood Process (*Class II*).—This is the same as the Robbins process previously described. Eighty-eight piles were prepared and placed in the Battery and Lombard-street wharves in 1877. The results were about the same as those in the Robbins method, but were lost by the construction of the sea-wall beyond the

wharves. J. C. Woods was the agent of the company that applied the Robbins process.

The Culver Process (*Class I*).—In this method the barked pile is first given a coat of "poisonous composition;" a coat of hot asphaltum is then applied and the pile wrapped with burlap, after which a second coat of asphaltum is applied. In 1873 five piles were prepared after this method and driven in Lombard street wharf. In 1877 five were put in Battery street wharf. But the best and most extensive trial was made in 1879, when eighty piles were prepared and driven in Green street wharf. Three years later these were examined and it was found that the covering had fallen off. In June, 1884, they were again examined, and it was observed that in rare instances had the covering remained; the piles had been very seriously injured by limnoria—more so than the other piles used in the structure, and left with their bark on.

Asbestos Felt (*Class I*).—This process consists simply in nailing on the barked pile a coating of asbestos roofing felt; unless very securely nailed on it tears and strips off in handling and driving the pile. Two piles were thus prepared and driven in Front street wharf in 1877. No note was kept of their condition until February, 1884, when they could not be thoroughly examined on account of the earth filling around them. The general appearance was, however, fair.

A Coat Tar Process, Name not known (*Class I*).—The protection in this process apparently consists in giving the barked pile a coating of pitch, of coal tar and asphaltum, and immediately rolling into the soft coat coarse sand and fine gravel. Fifty-seven piles were treated in this manner and driven in Front street wharf in 1877. They were examined in February, 1885, or six and a half years after being driven, and the entire failure was observed. There was no adhesion of the "protecting" coat below the reach of high water, and only traces enough to identify the piles were left above the reach of the water; in most instances the bark-covered piles were less injured than the supposed protected ones.

In June, 1882, five methods of protecting piles were attempted in the wharf at the foot of Mission street. These methods were given the names of the proprietors or inventors, and were as follows: The *Von Schmidt* process, the *Shay* (or *Duffey*) process, the *McKeon & Co.'s* process, the *Raye* process, the *Pearce & Beardsley* process. There were also tried cedar and eucalyptus piles. The five methods above given were all of the first class or coating process.

Mr. A. W. Von Schmidt's method was to jacket the pile, after driving, with iron-stone sewer pipe, and fill the space between the pile and the jacket with cement concrete. Two piles were thus treated.

Mr. Frank Shay's method is a modification of the Culver process (heretofore described); the modifications consisted, principally, in substituting wire cloth for the burlap, and in nailing it on, instead of trusting to the adhesion of the asphaltum. The barked pile was first given two coats of hot asphaltum, then wrapped with the wire cloth and given a third coat of hot asphaltum, and dusted over before cooling with sulphate of lime; 23 piles were tried. *McKeon & Co.* applied to the barked pile a coating of "marine cement"—it was applied like common whitewash, in four coats, time being given for each to harden (as much as it could). No information was given regarding the composition of this "marine cement," except that it contained an "extremely poisonous" substance of great protecting powers. Chief Engineer Bishop states that the coating did not adhere well in driving. Ten piles were experimented upon.

Mr. W. H. Raye coated the 20 piles prepared by him in a similar manner to those prepared by McKeon and Co. The coating was largely made up of Portland cement, the other ingredients were kept secret, but as subsequently proven, no valuable information has been withheld by the projectors of either of the two last processes. As in the McKeon method, the coating adhered to the pile very slightly, and fell off in handling and driving the pile.

Messrs. *Pearce and Beardsley's* process is another modification

of the Culver process; the main difference being the substitution of "Pearce and Beardsley's Compound" for the asphaltum coating, the burlap being retained. This "compound," so far as given in the records, consists of paraffine, kaolin, sawdust and limestone. It was applied hot, by pouring from a ladle and brushing down with a broom. After cooling, a coat of burlap was wrapped around the pile, and a second coat of the compound given; the protection adheres well at first. Five piles were prepared without, and thirty-nine with burlap.

In March, 1883, or nine months after being put in, these piles were examined by Chief Engineer Bishop, who reported as follows: "The two piles jacketed with drain pipe by Von Schmidt remain as when first put down. Of the twenty-three piles by Frank Shay, the covering of six is sound, fourteen are becoming rusty, the salt water having reached the wire cloth, and on three the covering is broken. Of the ten piles by McKeon, nine were found with the coating practically gone, and one is in a fair condition. Of the twenty piles of W. H. Raye, coating gone from all. Of the forty-four piles by Pearce & Beardsley, thirty-five are entirely sound, four have broken covering, and the five piles coated without burlap are almost entirely bare. The broken covering both on Shay's and Pearce & Beardsley's piles has the appearance of having been struck a blow or jambed."

In June, 1884, or two years after being driven, these were examined by Col. G. H. Mendell, Corps of Engineers, U. S. A., and the writer, and the following record made: "None of the processes showed permanence, nor any better results than the bark would have given, and most of them were in worse condition than the unprotected piles. The pipes covering Von Schmidt's piles were cracked, and one section on the south pile was entirely broken. This was probably due to the spring of the wharf, and the protection being too rigid and brittle.

McKeon's piles were almost entirely unprotected, and the coating adhering only in the upper part of the pile where not needed. Pearce & Beardsley's piles showed tolerably well, but there was no adhesion between the pile and the covering; same with regard to the Shay (or Duffey) process—the eucalyptus and

cedar piles were apparently in the same condition as when put in.

In 1882 the Pearce & Beardsley compound was applied to the chocks and ribbing on the ferry slips. This compound is principally refined maltha. It was applied hot with a swab. The edges of this timber now show that the limnoria have attacked it. Again, in 1883, it was applied to a suspended sewer under Washington-street Wharf; sufficient time has not elapsed for judging of the result. The cost of these latter applications was about two cents per square foot. Could the cost be reduced to one-quarter or less and a delay in the attack of only a few years be accomplished, the method would pay at the present prices of lumber.

In January, 1884, coal tar boiled to a tough pitch was applied hot to the chocks and ribbings below high tide in repairing Ferry Slips Nos. 5, 6 and 7. The cost was much less than the Pearce & Beardsley compound, but sufficient time has not elapsed for a fair comparison nor for definite results. This coal tar coating was applied only to *delay* the attack and not as an absolute preventive. At the same time a modification of the old Dutch process, of driving nails into the timber an inch or so apart both ways, was tried. This process has given remarkably good results in Holland and near New York. The modifications consisted in giving the timber a bath of diluted nitric acid in one instance, and of sulphuric acid in another, before driving the nails. The nails used were common eight-penny. The acid bath was given to hasten the oxidation of the iron. About the same date "Germicide" paint was tried. These have only been exposed about eighteen months, so that sufficient time has not elapsed for results to be given. Very recent examinations, however, show no attack.

It will be observed that no marked success has attended any of the experiments thus far tried, and this paper serves only to put them on record, that they may act as beacons rather than as channel buoys for future guidance. Failure has been mainly due to an absence of that *thoroughness* which is necessary to secure complete and durable protection. Many experimenters

have gone to work with the idea that some whitewashing process, or a perishable covering, pasted on with a supposed imperishable compound, was all that was needed, and that if the timber could only stand until it was once in the water, there would then be no causes tending to injure or remove it.

No covering depending upon its adhesion to timber will stand for more than three years when applied to green or freshly barked piles. The reason is obvious. The cambium and more recent rings of annual growth decay within that time, effectually destroying the bond. It is to be regretted that no thorough attempts have been made to saturate timber with creosote, a method so successfully and beneficially applied in Europe and some of the Eastern States. The only attempts made here in this line were the Robbins, Wood, Von Jensen, and the coal-tar processes; these hardly merit being classed as processes injecting creosote, so flimsy were the attempts.

The protection of timber is a question which the scientists of this Coast should take at once in hand, as the inroads already made into our timber belts are serious, and the increasing demand yearly mows down great swaths of forest. This denudation cannot long continue without greatly affecting our rainfall and floods, thus bringing the same disasters which have resulted in other countries directly from neglecting forest protection, and indirectly from neglecting the preservation of timber.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II.—JULY, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

July 10, 1885.

President Mendell in the Chair.

Minutes of preceding meeting read and approved.

P. J. Van Loben Sels was proposed as *associate* member by L. Heynemann, Geo. J. Specht and G. H. Mendell.

Marsden Manson read a paper on "Experiments in Protecting Lumber from Limnoria and Teredo in the Bay of San Francisco."

Mr. Specht called attention to the step taken by the American Society of Mechanical Engineers in having their Publication Committee select subjects for discussion at the meetings. Papers were now being printed before the meetings were held, and then discussed at said meetings.

He moved that a committee of three be appointed to consider the question of presenting subjects for discussion, which motion was carried.

The President appointed on said committee, Geo. J. Specht, Ross E. Browne and W. W. Hanscom.

The Executive Committee reported having sent out circulars to different societies asking an exchange of publications.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

VOLUME II — JULY, 1885.

DISCUSSION ON

EXPERIMENTS IN PROTECTING TIMBER FROM LIMNORIA AND TEREDO IN THE BAY OF SAN FRANCISCO.

DISCUSSION BY L. J. LE CONTE, COL. G. H. MENDELL, H. VISCHER, AND J. D. SCHUYLER.

L. J. LE CONTE, M. Tech. Soc.—Palmetto logs are not attacked by the teredo. Analysis shows that the fibrous structure of this wood is covered largely with a hard gritty siliceous coating not unlike that known to exist on the outside of ordinary cane, or rattan. It is very likely that this same character of material is contained in the bark of the piles used on this coast, and this fact renders that coating of such value in protecting the piles against the ravages of the teredo. It is therefore a purely mechanical obstruction to the entry of the young mollusk. A cheap impenetrable coating would seem to be all that is desired. But when we consider the rough handling which all piles have to undergo during construction, and the shocks and blows to which they will afterwards be subjected during rough weather, it would hardly seem possible that a cheap film or impenetrable paint

can be devised which could be relied upon to maintain an unbroken surface for any great length of time. I think our best hopes for success lie in the direction of some tough adhesive plaster, having in its composition certain ingredients which are known to be proof against the attacks of the young teredo or limnoria. If such a plaster can be devised which will stand intact through all the rough handlings connected with construction, then and there the entire question will be settled. I think there is absolutely no hope for success with poisonous impregnations; they wash out too soon, and the protective powers are lost. The same might be said of coal tar products, which are naturally and necessarily short-lived; no better proof is needed than their strong odor, which is evidence in itself of rapid decomposition.

G. H. Mendell, M. Tech. Soc.—A recent report of a committee of the American Society of Civil Engineers upon the subject of preservation of timber, states that when it is exposed to the attacks of the *teredo navalis* and *limnoria terebrans*, there is but one antiseptic that can be used to give protection. "This is creosote or dead oil, and the amount of it necessary depends upon the activity of the teredo, or rather upon the length of time during the year the temperature of the water renders them active. In our northern harbors probably ten or twelve pounds to the entire foot of timber are sufficient, but in southern seas it is probably necessary to inject fourteen to twenty pounds per cubic foot." At the Norfolk Navy Yard "oak piles cut in January and driven with the bark on have resisted four or five years, or until the bark chafed or rubbed off, and cypress piles well charred have resisted for nine years."

Our experience in California goes to prove that the bark so long as adherent affords protection, but that it is efficient only for a few years. While the injection into the wood of a sufficient quantity of dead oil will generally protect the timber, the method is not under every circumstance altogether practicable or satisfactory, and it is open to us to seek other methods of protection, not involving the introduction into the wood of antiseptics. If we can cover the faces of exposed timber by an armor insoluble or not oxidizable in sea water or air, and which

has sufficient hardness to resist the cutting tools of the marine animal, we may hope to secure a protection equal to that supplied by the antiseptic process, and in some respects superior.

When we reflect that the *teredo navalis* enters the wood by a boring not much greater in diameter than an ordinary needle, we can understand that its spheroidal cutters at that period of its life are liable to be broken by striking a slightly hard granular substance, and our knowledge of the *limnoria terebrans* leads to the opinion that such a coating would be an effectual defense against its attacks. Piles for special purposes are often coppered, but the costliness of the process limits its application. A coating of iron rust has afforded protection for many years both in Holland and in the United States. Sand, if applied to cover the surface in a permanent manner, would probably serve the purpose. Indeed any mineral substance combined in a mastic, insoluble in sea water, and adherent to the wood, would seem to promise to solve the problem of protection against the attacks of these animals. In order to be practicable under our California conditions the process must be cheap.

In some respects this system of protection would be preferable to the use of dead oil which produces the best results in porous woods, which alone can be made to take up the protection charge. It is found difficult or impossible to force twelve to twenty pounds of oil into a cubic foot of the compact and dense woods, which therefore cannot be fully protected by this process. This circumstance forces the use of inferior woods in these special cases of exposure, but an external armor will protect the best and strongest varieties equally with the inferior kinds.

The solution of this problem of external protection is therefore very desirable. The statement of the conditions might lead one to think the solution to be simple. It may prove to be so, when the true method is found, but so far the problem has resisted a number of experimental attempts at solution.

H. Vischer, M. Tech. Soc.—Certain Australian woods are said not to be attacked by the teredo — the eucalyptus-oak and the jarrah wood, a species much resembling mahogany. Teak wood is also but slowly attacked; and, among European woods, fir possesses the best. One powers of resistance effective, although

expensive protection, has been found in the use of a covering of woodwork with rawhide, or rather undressed cattle hides, which is not attacked by the teredo, and which under water does not rot rapidly. This method has been satisfactorily used in Germany and Holland for protecting the sills and portions of lock gates, but its use is of course a limited one. The studding of an exposed surface with broad flat headed iron nails (the heads 1½ inches broad and over) placed at intervals of every three or four inches apart has also been used with success. As regards the size which the teredo attains under favorable conditions, species have been obtained in tropical waters measuring considerably over an inch in diameter and upwards of four feet in length.

Jas. D. Schuyler, M. Tech. Soc.—In the waters of the Gulf of California the teredo and the limnoria are very destructive to all woods exposed to their ravages. My experience in the Bay of Altata, 120 miles north of Mazatlan, with pine piles from Puget Sound driven for a railroad wharf, was that the bark was little or no protection to the pile. The teredo had cut through the bark and attacked the wood within three months from the time the piles were driven. After passing through the bark they frequently attained a size of fully one-half inch diameter. Chipping off the bark with a hatchet (at three to four months from the driving of the pile), I found it honeycombed with teredo that were entering the solid wood with a cut the size and shape of the end of one's finger—semi-spherical. Within twelve months the piles were well honeycombed, and in eighteen months were so weakened as to be dangerous. I could not observe that the limnoria attacked the bark, but wherever the wood was exposed, their progress was rapid. They cut off the 4x12-inch sway braces on the wharf with astonishing rapidity. The temperature of the sea water was 80° to 85° Fah. Barnacles and sea moss gather very rapidly on the bottoms of vessels in those waters. Barnacles formed and grew to a depth of two to four inches in as many months on the bottom of our iron coasting steamer, in motion more than half the time.

The native woods of Mexico have better resisting qualities against attacks of teredo and limnoria than those used for wharves

in the United States. In Mazatlan I was shown the remains of a wharf built of piles from the *palo prieto* and *jaba*, that had been cut down after being in use twenty years. The stumps exposed at low tide seemed to be sound. Piles can be obtained of these woods with some difficulty thirty feet in length. Ebony resists both these pests a great length of time, and is very abundant on the west coast, but it rarely grows to the dimensions required for piles. The cocoanut, palm, and all other indigenous woods, seem to be proof against teredo and limnoria, but I know of no attempt to use them for marine structures, doubtless on account of their lack of strength.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXIV.

(VOLUME II —AUGUST, 1885.)

ARE NOT DYNAMITE CATASTROPHES INTIMATELY ASSOCIATED WITH ELECTRIC PHENOMENA?

By L. J. LECONTE, Mem. Tech. Soc.

Read August, 1885.

Dynamites taken as a class, constitute the most reliable and powerful explosive agent that the constructive engineer has at his command, and as a natural consequence, they have been subjected to a great many experimental investigations. During the past ten years, I have studied in particular the subject of Dynamite catastrophes on the Pacific Coast, and contribute the following facts and conclusions for consideration and discussion.

Having great confidence in these explosives, I take special interest and pleasure in submitting the results of my own observations and experience as a consumer, with the hope that I may be able to throw light on the dreadful questions surrounding the true causes which give rise to the destruction of dynamite factories in general, and especially those in California.

Although my attention has been drawn to this subject for the past ten years, yet a systematic study was not undertaken until 1878. After studying up the literature on Dynamite, it was ascertained that writers maintain that acid nitro-glycerine de-

composes and becomes very sensitive when the temperature reaches 100° Fahr., and furthermore matters should be so arranged that the sun cannot shine directly on nitro-glycerine or dynamite, as the direct heat of the sun causes decomposition to ensue in nitro-glycerine.

As I expected to encounter the direct heat of the summer sun, with temperatures of 115° to 128° Fahr. on the Sacramento river, some anxiety was felt as to the probable consequences. Operations have been going on for over seven years, and we have not had a single accident.

Singular to relate, however, during these very same years, terrific explosions with fearful loss of life were taking place at the manufactories on San Francisco bay; and, mark you, while we were using the self same dynamite, manufactured by the works that blew up.

A great deal of thought was then given to collecting and digesting the facts connected with these explosions. The data obtained from journals and reports of coroner's inquests were found to be so fragmentary and contradictory that the whole matter was several times laid away in hope that better light might some day be discovered.

Finally, however, on March 4th, 1881, the "Eureka Powder Works," Steges station, Berkeley, blew up under conditions so remarkable that the whole subject became presented to me in an entirely new light.

I then set to work with renewed vigor and overhauled all the past history of these catastrophes, as contained in the daily reports and investigations on the public files.

The compilation of these facts, together with my own notes, furnished a fair record of all catastrophes as far back as November 26, 1869, embracing no less than five separate and distinct dynamite explosions.

An investigation of all these facts developed the following remarkable results:

1. My attention was attracted to the fact that all these explosions took place during violent dessicating north wind storms, peculiar to the winter and spring months in California, *without exception.*

2. Next, it was observed that when the explosions did occur in mid-summer, as on June 21st, 1872, even then they took place invariably during a dessicating north wind storm.

3. The next point observed was that when an explosion took place, it *never* occurred on the first day of the storm, but on the third or fourth day of its continuance. This fact showed that a certain degree of dessication or dryness of the air was in some way essential to furnish the peculiar conditions necessary to bring about a disaster.

4. The next point observed was the prodigious amount of electricity developed on my person by friction of clothing, more particularly when walking against these dessicating north winds. The same phenomenon showed itself in a popular form, well known to all Californians, namely, in the effect which these winds have on the hair and tails of horses. The bristling of the hairs all over the body, even when the animals are at work, is quite remarkable; not only so, but very frequently the bristling of the tail is so great as to increase its diameter four or five times above the natural dimensions. These dry north winds have a velocity of 50 miles per hour, and a relative humidity of about 20 per cent., but frequently as low as 15 per cent., and seldom as low as 5 per cent.

I then called upon Mr. A. N. Towne, General Manager C. P. R. R., and asked him if the company had any trouble with their telegraph lines. He replied that at the very time of the last explosion, the wires could hardly be worked at all; and it may be stated as a general fact known to exist during all these dry north winds.

By still further investigation it was ascertained that the telephone lines throughout the region likewise found great difficulty in keeping up intelligent communication with the different centres.

These invaluable pieces of information, coming from such reliable sources, added great weight to the growing chain of evidence, and are important in showing that these electrical disturbances were not only great in intensity, but also wide-spread and general in their effects. So confident had I become as to the

true controlling causes of these catastrophes that about the middle of March, 1881, I began to study these dry north wind storms, with the view of actually predicting future explosions.

PREDICTED EXPLOSIONS.

My first prediction was attempted on January 9th, 1882, when a dry north wind set in. I stated to several of my friends that in accordance with past history, there ought to be an explosion of some kind on the third day of the storm. Sure enough, on January 11th, the Hercules Powder Works, at Pinole Point, blew up, killing and wounding five operatives.

My second prediction was made on March 25th, 1882, the first day of a dry north wind. As before, I predicted that an explosion would occur on the third day of the storm. Sure enough, on March 27th, 1882, the Vulcan Powder Works, at Steges Station, blew up, killing and wounding sixteen men.

My third prediction was made on January 18th, 1883, the first day of a dry north wind storm. Sure enough, on January 19th, the *second day* of the storm, and a little ahead of time, a small explosion occurred at the Nitro-Safety Powder Co's Works, killing two men. Again, however, on January 21st, two days after, and the fourth day of the storm, a dreadful explosion took place at the Giant Powder Works, at Point Isabel, killing and wounding between forty and fifty operatives. Here we have a case in which two explosions occurred during one storm.

My fourth prediction was made on June 5th, 1883, the first case of a dry north wind during mid-summer. As before, I predicted that an explosion would take place on the third day of the storm. Sure enough, on June 7th, 1883, three tubs of nitroglycerine at the Nitro Safety Powder Works blew up. No casualties.

These remarkable coincidences, embracing all the cases of powder works explosions extending from 1869 to 1883, some ten catastrophes in all, certainly deserved public attention. I was just on the eve of publishing these important facts when a most remarkable exception to the north wind theory occurred. This

was on September 29th, 1883, when the Hercules Powder Works blew up with terrible results, killing and wounding forty to fifty men. This explosion was entirely unpredicted, and for the time being I was quite nonplussed. A careful investigation, however, developed the potent fact that this explosion took place on the immediate approach of one of the most violent thunder storms ever witnessed in this region. The daily journals commented on the storm, and many of the neighboring citizens confounded the powder works explosion with the crashing noise of thunder bolts.

After considering the facts, it became evident that this so-called exception, instead of detracting from the north wind theory, added almost conclusive evidence, and as it were, clinched the whole subject matter under consideration.

The above statements contain the gist of all the facts I have been able to collect so far, and I think there can hardly be a shadow of doubt but that electricity, in some shape or form, is the controling element or the great ruling feature accompanying all these dynamite catastrophes.

It naturally occurred to me, while studying this subject, that if electrical manifestations of any great violence did take place in the manufactories, then some one of the operatives or managers would certainly have noticed the fact or had their attention called to it in some way. With this end in view, I again went over all the testimony given at the inquests held by the coroners. My researches in this direction were void of any definite results, principally from the general fact that when an explosion occurred, it made a clean sweep of the entire site, and no one was left to tell any tales. Finally, however, my attention was called to the testimony of a man who was formerly an operative in the powder works. He testified to the fact that he had seen sparks fly during the manipulation of the ingredients, and that he had quit the works on that account.

The best evidence on this point, however, is that obtained from an entirely unexpected quarter, namely, from parties engaged in the construction of the Sutro Tunnel, near Virginia City, Nevada. Several fatal accidents occurred on these works while the men were handling dynamite, and a study of the facts showed that they occurred always during these same dry north

wind storms. But the most conclusive evidence is that furnished by Mr. Charles Hoffman, Mining Engineer, who states that the President of the Company, Mr. Adolph Sutro, while in his office, and during the progress of one of these dry north wind storms, attempted to pick up some copper caps which were lying on the table, when an explosion occurred and he nearly lost his life. The writer knows that during these dry wind storms any one who will try the experiment can easily excite enough electricity on his person to give off a spark *half an inch long*, and with care and a little experience can light a gas jet.

Corroborative evidence from other sources and authors has been collected. The most instructive and reliable data on this subject, I obtained from Mr. F. H. Jenssen's paper, published by this Society last November and December. Mr. Jenssen being an intelligent manufacturer, his statements showing the actual condition of affairs in the works during the progress of operations, have great weight, and from my point of view, certainly furnish additional evidence that electricity is the true cause of these disasters. I quote from him in full, italicizing such portions as may require emphasis: "At another powder factory where the wash water had been conducted through a ditch in rocky ground, it was subsequently discovered that the rock was fissured, and that a large amount of nitro-glycerine had accumulated in the seams. It was concluded to dam the ditch and keep the fissured portion permanently under water, wherever the nitro-glycerine could be traced. Several years passed, when suddenly *during a heavy storm*, the middle of the ditch was struck by lightning. A terrific explosion immediately ensued, damaging severely all the buildings in the vicinity, and hurling to a great distance vast masses of rock."

Again we have a case as late as July 2d, 1885, at Cheyenne, on Central Pacific Railroad:

"This afternoon, lightning struck a powder magazine, one mile north of this city, causing an explosion of three tons of giant powder."

Having studied carefully all the physical conditions outside the buildings of the manufactories, I next directed my attention to collecting facts in regard to the conditions which exist inside

the buildings. I am particularly indebted to Mr. Jenssen for this most valuable addition to my collection of facts. He says in his paper above mentioned:

"The absorbent is dried before it is mixed, and the drier it is the better the powder. It is hydroscopic, and therefore should be taken from the drying directly to the mixing pan. Should it be too hot, the nitro-glycerine will decompose, and an explosion, or at least combustion will occur. The dust, which arises from the mixing pan, settling everywhere in the building, is a source of great danger. Therefore the hot water or steam heating pipes should be covered, so that the heat may enter the room and the dust prevented from settling on them. Moreover, they should be cleaned regularly, so as not to give the small particles of nitro-glycerine contained in the dust an opportunity to decompose. Nitrated cotton, when used in a dry and finely pulverized state to manufacture Nobel's Explosive Gelatine, makes a great deal of dust, and special care must be taken that this dust does not remain during the night on the pipes. An accident which happened several years ago in the mixing house of an Italian factory, has been attributed to this cause. Direct heating with stoves should be avoided, and in Europe is not allowed. The hot-water heating system is now in general use. Since its introduction, accidents in the mixing as well as packing departments, have decreased."

CONCLUSIONS DRAWN.

After a careful study of the above facts, I have come to the following conclusions:

1. That electricity is the exciting cause in all cases.

2. That the first explosion in the works is a phenomenon of dust explosion, and that the great powder explosion, apparently instantaneous, is nevertheless a secondary result.

My reasons for this belief are based upon recent discoveries made bearing upon the subject of "dust explosions," and as the results are of great public interest, I will submit a synopsis of the facts.

DUST EXPLOSIONS IN GENERAL.

This subject has been much studied and discussed of late years, and as a result, we have a large amount of valuable information published. The dreadful explosions in the cotton manufactories in the New England States, as far back as 1847, have been traced to " cotton dust." The exciting cause being electric sparks given off from the belting used in the machinery. Also the flour mill explosions in the Western States have been likewise traced to the same source, namely, flour dust.

The latest contribution to our knowledge on this subject is contained in a series of articles published by a Mr. Galloway, on Explosions in the English Collieries, in which it is shown beyond question that a large percentage of the terrible explosions in coal mines, commonly attributed to " gas explosions," are due not to gas at all but to the air in the mines, *being very dry*, becoming filled with fine impalpable coal dust, and thus giving rise to " *dust explosions.*"

A careful study of the history of these dust explosions and the physical conditions which accompany them, leads to one general conclusion, namely, that any combustible substance whatever in a finely divided form, when mixed with a certain proportion of *dry air*, will constitute a very dangerous and explosive compound.

The least spark, such as is likely to arise from machinery or the accidental collision of stone or metalic substances, is sufficient to cause an explosion or conflagration.

Now, then, let us see how these facts apply to the cases of powder-works explosions in California.

1. Our observations show that, so far at least, eleven-twelfths, or 90 per cent. of all the explosions on this coast have been during violent dessicating north wind storms. The relative humidity being generally 20 per cent., sometimes as low as 15 per cent.

2. Mr. Jenssen states that in the process of manufacture the rooms in the building are more or less full of dust from the dry absorbent used in making dynamites, and that this dust, on examination, is found to be *saturated with acid nitro-glycerine.*

It would be difficult to imagine conditions more favorable for the phenomena of "*dust explosions*" than exist in these manufactories, particularly during the dry north-wind storms above mentioned. The slightest spark, either electric or otherwise, is all that is wanting to create an awful catastrophe.

PRECAUTIONS AGAINST DUST EXPLOSIONS.

As may be naturally inferred from what has gone before, the great safeguard against "dust explosions" is moisture in some shape. It dissipates all electrical manifestations, moistens the particles of dust and causes them to settle to the floor by excessive weight. Thus the conditions governing dust explosions become annihilated to a large extent.

In 1847 the managers of the State of Maine Cotton Mills introduced steam into the rooms where dust explosions had previously occurred, and the air was maintained at a certain degree of moisture. Since that time there have been few, if any, explosions in the mills.

The same practice has been applied with success to preventing the flour-mill explosions.

Also in the English collieries it was found that *excessive dryness of the air* constituted the fundamental difficulty.

This dryness gave birth to all the other physical conditions which bring about dust explosions.

As in the case of cotton mills, the English colliery agents are now using steam jets to keep the air in the mines in a moist condition. This accomplishes two purposes, namely, it allays the dust floating in the air, and at the same time dissipates all electrical manifestations.

The above outline of experience in dust explosions naturally suggests the application of the same principle to preventing dust explosions in the dynamite works.

I think there can be no question about the complete efficacy of this plan in stopping the majority of these disasters, that is to say, all such as are likely to occur during dry north-wind storms.

EXPLOSIONS DURING THUNDERSTORMS.

The above paragraphs, it will be noticed, treated almost exclusively those explosions which took place during dry north winds.

We will now take up the explanation of those cases which occur during thunder storms.

An extensive and interesting paper might be written on this subject alone, but I will confine myself solely to the final conclusions arrived at.

These thunder storm explosions are likewise undoubtedly due to electrical phenomena, the manifestation of which show themselves frequently in a forcible manner.

The most probable cause leading to these explosions, is what is generally known as "*return shocks*" or "*ground strokes,*" which always accompany violent thunder storms.

These same phenomena have been observed at the City Hall, in Oakland, by the Fire Alarm Department and Telegraph offices in that vicinity. In many cases the wires have been melted and the alarm boxes set on fire under circumstances which prove conclusively that the source must be due to ground shocks.

These local facts are very important in that they furnish positive evidence that ground shocks of considerable violence are quite common in the neighborhood of the several powder works in Contra Costa County.

I think there can hardly be a shadow of doubt but that a ground shock was the true cause which gave rise to the fatal explosion of the Hercules Powder Works, on September 29th, 1883; and I furthermore believe that the explosion at Cheyenne, on July 2d, 1885, may be traced to the same source.

A wrong impression has long existed in the public mind in regard to lightning, which is very hard to eradicate, namely: most people suppose that all fatal strokes of lightning necessarily come from a thunder cloud overhead, whereas in point of fact a large percentage of them come from the ground in the form of a return shock.

A stroke of lightning from a cloud has only a local effect at the particular point where it may strike, whereas the return

shock, induced by the electrified cloud, may shock the entire country around that point for twenty square miles, depending on the size of the cloud.

Within the past week we have had a fearful example of these return shocks, as experienced by the parties at Mt. McGregor engaged in making preparations for Gen. Grant's funeral.

The reports by telegraph state:

"1. A violent stroke of lightning hit the brow of the hill at 7 o'clock P. M., while the guests were at dinner."

"2. Balls of fire shot from the electric globes over the table with loud reports."

"3. Balls of fire also bounded from the telegraph instruments in the hotel lobby, in rapid succession, like rattle of musketry. A panic ensued."

Next came news of similar character from the R. R. Station.

"4. Gen. R. H. Jackson and Colonel W. B. Beck were walking down the roofed arcade some distance above the station, when both were knocked insensible. They fell as if struck by a sledge-hammer. They happened to be under an electric lamp at the time of the shock."

"5. Also a lady in the waiting-room at the railroad station was knocked down insensible while standing near the electric lamps. Four others on the platform outside were also knocked down, as well as half a dozen soldiers who happened to be lingering about the place."

"6. A woman at a laundry near by was also stunned, but not seriously hurt."

CAUTIONS TO BE OBSERVED.

There is one well known and important fact to be remembered in connection with all these ground shock phenomena, namely, that in any given locality the electric fluid, in returning, always follows along the best conductors with which it may come in contact, and hence we find it flowing along such channels as gas-pipes, water-pipes, but more particularly, the wires of tele-

graph, telephones, electric light wires, and also railroad tracks. After traversing these conductors the fluid jumps off the further extremities in the form of a series of violent electric sparks, making a rattling noise not unlike the firing of musketry, and very frequently destroys life.

FINAL REMARKS.

In applying the above information to the betterment of conditions at the powder manufactories, a great deal of study is necessary. Local peculiarities have a powerful influence in determining the best plan to be adopted in any given case—in other words, each case is necessarily a special study in itself. There are, of course, some fundamental precautions which should be observed by powder works in general, without exception, namely: All good conductors of electricity should be prohibited from entering the buildings where explosives of any nature are stored or manufactured, and it would be a wholesome rule not to allow such conductors to be anywhere near the premises. These remarks apply with equal force to all manufactories where ordinary black powder is made as well as to military magazines where ammunition is stored.

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TRANSACTIONS.

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XXV.

VOLUME II.—SEPTEMBER, 1885.

THE LOCATION AND CONSTRUCTION OF THE RAILROADS ACROSS THE ALPS.

By GEO. J. SPECHT, M. Tech. Soc.

Read September 5th, 1885.

Introduction.—The Alps separate Northern and Central Europe from Southern Europe, and make traffic between them difficult. The warfaring Romans surmounted them; they built roads across them, eighteen in number, some of which are still in existence. These roads were altered considerably during the middle ages, and still more during the last century. Most of them were abandoned at the beginning of the present century, and new ones were built, varying in width from 20 to 26′, and with maximum grades from 370 to 634′ per mile. The first and best of these new roads was built by Napoleon I., across the Simplon, in 1800–6. Soon after, the roads across the other Alpine passes were built.

At present, 90 stage roads of the first order and 60 of the second order, cross the Alps. They are difficult to pass during the winter. Some of them are open for traffic only from May to middle of October, on account of snow blockades. The passes crossed by these roads vary in elevation from 5,900′ to 9,200′

above sea level. This fact made the construction of railroads across the Alps, which would be open during all times, very desirable.

The rough nature of the Alps, with their narrow, very sinuous and steep valleys, enclosed by precipices and high mountains, makes the location and construction of a railroad a very difficult undertaking. The inclemency of the climate does not permit to ascend into the higher parts of the Alps, as the traffic would then be exposed to frequent and extended interruptions. All of the Alpine railroads, except one, cross the Alps through a long summit tunnel under high mountains. The Mount Cenis tunnel is 7.56 miles long, with 5,250′ feet of rock above it. The Gotthard tunnel is 9.3 miles long, and the rock above it is 5,650′ high; and the Arlberg tunnel is 6.35 miles long, and the mountain over it is 2,300′ high above the tunnel level.

The highest elevations of the Alpine railroads are comparatively low (see table I); that of the Brenner railroad is the highest, 4,485′ above sea level. It is the only open railroad crossing of the Alps.

TABLE I.

Name of R. R.	Beginning and End of Railroad.		Highest elevation of the railroad.	Length of the summit tunnel.	Length	Maxim. grade	Sharpest curve	Year of opening R. R.
	Name.	Elevation above sea lev'l			of the railroad.			
		feet.	feet.	feet.	miles.	feet per mile.	degrees	
Semmering (double track.)	Gloggnitz.	1440	2946	4692	26	132	8° 15′	1853
	Muerzzuschlag	2231						
Brenner... (double track.)	Innsbruck.	1903	4485	no tunnel.	77.9	132	6° 7′	1867
	Botzen.	853						
Arlberg.... (single track.)	Innsbruck.	1903	4299	33,587	84.4	165.8	7°	1884
	Bludenz.	1831						
Gotthard.. (single track.)	Immensee.	1519	3786	49,016	109	142 6	6° 15′	1882
	Pino.	764						
Mont Cenis (single track.)	Bussoleno.	1588	4390	40,124	48.3	158.5	5° 5′	1871
	St. Michael	2494						

Semmering Railroad.—The first railroad built across the Alps is the Semmering road from Gloggnitz to Muerzzuschlag (Figs. 1

and 2), being a link of the road from Vienna to Trieste. It was opened for traffic in October, 1853. It is 26 miles long, double track. The mountains traversed are steep and precipitous. There are 15 tunnels including the summit tunnel, 4.692′ long; 16 bridges and viaducts, all built of cut stone. The highest elevation reached by this railroad is 2,946′, in the summit tunnel. The maximum grade is 132′; minimum grade 53′; and average grade 64′ per mile. This road is characteristic for its expensive construction.

The sharpest curve is 8°15′ (formerly 9°30′). Every two miles the maximum grade is interrupted by horizontal sections about 1,800′ long. Two reversed curves are connected by a tangent from 90′ to 150′ long. The longest curve of 9°30′, was 2,040′ long, half of it being on a grade of 88′, and half on 117′ per mile. The air-line between Gloggnitz and Muerzzuschlag is 12.25 miles; the pass is 5.65 miles distant from Gloggnitz, and 1,897′ above it; which corresponds to a direct grade of 330′ per mile The highest point of the railroad is 314′ lower than the pass and is 73,420′, or about 13 9 miles longer than the air-line. This length is attained by using each lateral valley to develop the line. The road has a double track, the road-bed being 25′ wide. The mountain sides of the valleys traversed are nearly vertical [Weinzettel-wand being 3,800′ perpendicular, the road passing it 400′ above the valley]. High embankments and deep cuts do not occur on this road, as the slopes are too steep. Instead of that long walls of solid masonry are used; in fact, structures of masonry are so frequent that, taking into account the viaducts and tunnels, the Semmering railroad can be considered as one piece of masonry.

The engines used on the Semmering road weigh, including tender, sixty-six tons. and are able to pull a train of one hundred and seventy tons up a grade of 132′ per mile, and in curves of 9°15′. In wet weather this capacity is reduced by 25 per cent. The latest engines weigh forty-four tons when empty, and fifty tons when ready for service; have cylinders 19″x29″, and pull two hundred tons up a grade of 132′ per mile.

Mont Cenis Railroad.—The second railroad built across the Alps is the Mont Cenis railroad. (Fig. 3.) The principal struc-

ture of it is the tunnel, traversing the mountain chain below Col de Fréjus. It is 7.56 miles long. It was commenced in 1857, by the Italian government on the south side, and in 1863, by the French government on the north side. The two headers met on December 26, 1870, and the tunnel was opened for traffic on September 17, 1871. The tunnel entrance on the north side is near the French village Madona, and the exit is near the Italian village Bardonecchia. The highest elevation reached by the road is in the tunnel, 4,390′ above sea level, and 5,275′ below the top of the mountain. The tunnel is arched with stone masonry for its entire length. The rock traversed, from Madona to Bardonechia, is sandstone, rich in mica, intermixed with slate, quartz, anhydrite, limestone and dolomite; then crystallinic limestone and dolomite encircling clayish slate. 5,250′ of the headers were driven by hand labor, the rest of the tunnel by machine drilling, using compressed air. The total cost of the tunnel was $14,000,000. The actual cost of the Italian railroad from Bussoleno to Bardonecchia, the exit of the Mont Cenis tunnel, was as follows:

Cost of construction, 25 miles	$5,166,000
" " " of one mile	206,640

It took eight years to build this section. About one half of the section runs through comparatively easy ground, and is built for a double track. The cost per mile of the other very heavy part (single track) was $177,420, exclusive of rolling stock; that of the easier part (double track) was $118,000 per mile.

Brenner Railroad.—At the same time the Mont Cenis railroad was built, the Brenner railroad in Tyrol, Austria, was constructed. It is the only Alpine road which crosses the Alps in an open line. The Brenner Pass is 4,482′ above sea level, and is passable at all times. The Romans used it as their main road between Verona and Augsburg.

The Brenner railroad, 77.9 miles long, connects Innsbruck, the capital of Tyrol, with Botzen, in South Tyrol. It runs mostly along the main valleys, leaving the same only twice, to obtain the necessary length to overcome the steeper grades of the valleys. At the end of each of these developments are tunnels.

The side slopes of the valleys are very steep. The longest part of the road is in deep cuts and on high embankments. In contrast to the Semmering railroad the Brenner has only few costly structures, as bridges and viaducts. The leading principle in its location, was to follow the natural lay of the country as long as possible, to avoid bridges, long and expensive retaining walls, and to build the road in cut and fill. Twenty-seven tunnels are on this line, but none of them very long, the longest being 2,808′. The maximum grade on the north side of the Pass is 132′ per mile (22 miles long), and on the south side 120′ per mile (31 miles long). The rock of the mountains is principally porphyry, serpentine and clayish slate, difficult to work. The air-line between Innsbruck and Botzen is 52 miles long, 26.1 miles shorter than the railroad.

The most difficult part of the Brenner railroad was that from Innsbruck to Matrei, 10.6 miles long; 15 per cent. of this are in tunnel. The actual cost of constructing this part (exclusive of track, station houses, rolling stock, etc.) was:

	Total.	Per one mile.
Open line	$2,373,933	$263,770
Tunnels	1,117,760	693,400
Total	$3,491,693	$329,400

The cost of constructing the entire road from Innsbruck to Botzen, 77.9 miles long (74.83 in open line and 3.07 in tunnels), was (exclusive of track, station houses, rolling stock, etc):

	Total.	Per one mile.
Open line	$8,516,223	$113,800
Tunnels	2,046,033	664,462
Total	$10,562,256	$135,587

The chief engineer of the Brenner railroad was W. Thommen, and his first assistant W. Hellwag, the late chief engineer of the Gotthard railroad.

Gotthard Railroad.—The next Alpine railroad built was the Gotthard railroad in Switzerland. It was the most difficult one to locate and construct, and is the most interesting one. It has

many unique features which no other railroad has, necessitated by the climatical and elementary conditions of the country traversed.

Topography.—The mountain divisions of this road run along the Reuss valley on the north side of the summit tunnel and along the valley of the river Ticino on the south side. The Reuss issues into the lake of the Four Cantons, and the Ticino into the Lago maggiore. They are both mountain streams with numerous tributaries, which have their sources in the highest regions of the Alps, fields of eternal snow and glaciers. They supply large and continuous streams of water, which at times assume suddenly immense proportions.

Principle of Location.—The total length of the valleys is sufficient for one continuous railroad grade from the lower termini of the mountain divisions to the summit tunnel; but such a line would be along very difficult mountain slopes, which would make the construction very expensive and the operation of the road dangerous. The railroad as actually built, occupies the bottom of the valley, and the best and safest ground near the stage road as long as the natural grade of the valley allows it. The sudden breaks in the grade and cataracts have been overcome by artificial development. Neither of the two valleys have lateral tributaries available for a development of the line. The length required to ascend the cataracts has been obtained by spiral tunnels, which are a characteristic feature of the Gotthard railroad.*

The mountains traversed belong to the tertiary period. The valley slopes are in a continuous state of instability. During the winter months the ground is in a comparatively quiet state; it is covered with immense masses of snow and ice, which come down into the main valley, sometimes suddenly, in form of avalanches, destroying everything before them, and blockading the road. The dangers of these geological and climatical conditions

*—The underground development curves have not been built as an imitation of the Tehachapi loup of the Southern Pacific Railroad, which is nothing but an open line dictated by nature by following the contour of the country with a certain maximum grade. The circular tunnels of the Gotthard railroad are entirely original with the late Chief Engineer, W. Hellwag, who was one of the most prominent railroad engineers Europe has ever produced.

require a very careful location and construction of the railroad. Each case had to be studied separately and be treated individually; numerous viaducts and bridges had to be built; also galleries and strong archways to protect the road against mountain slides and avalanches; aqueducts to lead torrential streams over the road; tunnels to avoid the dangers of avalanches and mountain slides.)

Capital of the Company.—The money necessary to build the Gotthard railroad was contributed partly from interested Governments, in the form of subsidies, and partly by a stock company. The Government of Italy contributed $11,000,000; Germany, $6,000,000, and Switzerland, $5,600,000. By subscription $22,800,000 were obtained. Besides this, a sum of $2,400,000 was raised for the construction of the line Ginbiasco-Lugano. This makes the total capital for the construction of the Gotthard railroad $47,800,000. The subsidies (total, $22,600,000) shall be entitled, in place of interest, to half the net proceeds as soon as the dividends to the stockholders are larger than 7 per cent. The shares (total, $6,800,000) were issued at 92 per cent. Of the first mortgage bonds ($14,800,000), $13,600,000 were sold at 95 per cent, and $1,200,000 at 78 per cent; the contractors took 10 per cent of their payment in second mortgage bonds ($1,200,000) at 75 per cent, which, however, was soon abandoned, as the company could sell the bonds at better rates.

Description of the Line—Northern Valley Division.—The northern terminus of the Gotthard railroad is the station Immensee (1,519′ above sea level) (Fig. 4). The line then hugs the north-eastern slope of the Rigi, connecting at Goldan with the Arth-Rigi railroad, and passes over the mountain slide of Goldan (occurred on September 2, 1806, burying in half an hour three hundred houses and four hundred and fifty-seven persons); then it turns to the southwest and reaches the summer-resort, Brunnen, on the shore of the lake of the Four Cantons; from there it runs along the shore of that part of this celebrated lake, which is called Urner Lake. This shore consists of perpendicular mountains (the water being 650′ deep in part of them) which are interrupted by only a few gorges. The rock is limestone, easily

disintegrating. This section (Brunnen Fluelen) is 6.2 miles long, of which 3.3 miles are in tunnels; the nine tunnels have an aggregate length of 17,424 feet. The tunnels were built rapidly by the aid of numerous lateral drifts, opening out to the lake; hand-drilling only was used. The monthly progress in each advance-header (top-header) was from 92′ to 105′. Having passed the last of these tunnels, the very extensive talus of the Gruenbach is crossed; this is a very dangerous torrential stream, depositing large masses of débris at times. The railroad crosses it in an open line; the torrent is carried over the road, and large wing-dams are built to protect the same. Then the line reaches the end of the lake at station Fluelen, and continues in a straight line up the Reuss Valley to station Erstfeld, where the mountain division commences.

Northern Mountain Division.—Some distance below Erstfeld, the geological formation changes; the limestone formation ends, and gneiss, granite and micaceous slate commence, which continues to the Gotthard tunnel. The railroad now ascends along the right side of the valley to Amsteg, passes through a tunnel 595′ long, and immediately after over the Kerstelenbach on an iron viaduct, two spans, each 164′ long (weight of iron 298 tons), with a masonry centre pier 167′ high. The grade of the road is 137′ per mile. Then the line passes under the channels of several very powerful avalanches in two tunnels of an aggregate length of 2,014′. The river Reuss is then crossed on an iron bridge, one span of 253′, 213.5′ above the river-bed, (weight of iron, 370 tons.) Now the road runs along the left side of the valley, passing over several small bridges, tunnels, a viaduct of three spans, a 98.7′ span (iron girders, weight 182 tons), with two piers of masonry 85.4′ high, and another viaduct of masonry with 6 arches each 33′ span. The station Gurtnellen is reached next, its elevation above sea level is 2,430′. The line is now near the bottom of the valley; about a mile beyond the station is the first cataract of the Reuss, the Pfaffensprung gorge; the grade of the valley is too steep to be available for a railroad. The difference of elevation between the lower entrance of the Pfaffensprung tunnel and the north portal of the Gotthard tunnel is 1,084′; the length of the valley between these points is 22,000′, which gives

an average grade of 260′ per mile. The railroad between these points is 48,200′ long, or 26,200 longer than the valley. This length is gained by an artificial development, including three circular tunnels. (Fig. 5.) The first of them, the Pfaffensprung tunnel, is 4,840′ long, and forms a compound curve of 6° 15′ and 3° 30′, grade 121′ per mile. The rock passed through was a very hard gneiss with granite. The construction of the tunnel was begun with a top advance header, 86.4 square feet cross section, with percussion drills, later continued and finished with hydraulic drills and bottom header, cross section 64.7 square feet; average progress per month 180′. A top header was driven from the upper mouth of the tunnel by hand, monthly progress 65.6′. The tunnel is built for double track. Its construction took two years and nine months. After the two advance headers were connected (April, 1881), the enlargement and finishing of the tunnel took five months. This tunnel and 2,150′ of the continued line, with a grade of 137′ per mile, have raised the road 167′, being now nearly 200′ above the bottom of the valley. The road then ascends with a grade of 132′ per mile, between the stage road and the steep mountain sides toward the station Wasen, where a second artificial development is necessary. At the village Wasen, the railroad is again near the bottom of the valley, and encounters the second cataract. The railroad crosses the river Reuss, passes through the Wattinger tunnel (second circular tunnel, 3,560′ long), turning in the same to the right, recrosses the Reuss, runs along the same slope it ran along before, but in the reversed direction, until it enters the third circular tunnel (the Leggistein tunnel, 3,590′ long), in which it turns to the left, running again along the same mountain slope on which the lower two lines ran. The lowest and highest part of the line approach each other horizontally about 500′, while their vertical difference is 410′. For a distance of about 1.6 miles, three lines run nearly parallel to each other in different elevations. Both of the circular tunnels have a grade of 116′ per mile and curves of 5° 50′. They were built by hand labor, top-header, from 65 to 96.19 square feet large. Average monthly progress from 56 to 69′ at each face. The Main Reuss is crossed twice on iron bridges of 131′ resp. 147.5 span. The Mayen-Reuss is crossed three times, on iron bridges of 131′, 213.5′ and 180.4′ span. At the end of

this development the railroad is 426′ above the bottom of the valley. The wild and dangerous torrent Rohrbach it crosses on an iron arch, 196.7′ span, weight 247 tons. The dangers threatened by the numerous avalanches along this part of the Reuss valley are avoided by building the railroad under ground. The Naxberg tunnel is 5,160′ long; hard gneiss granite; hand labor; top-header from both sides and 4 lateral drifts; double track; one-fifth of the tunnel is lined with masonry. After leaving this tunnel, the road ascends the valley with a grade of 132′ per mile, crossing the wild Goeschener Reuss on an iron bridge of 213.5′ span and 98.5′ above the bottom of the stream. Then it enters the station Goeschenen, 3,640′ above sea level. The north porta of the Gothard tunnel is reached after leaving the station, and crossing the main Reuss on an iron bridge of 92′ span.

The Gotthard Tunnel.—The Gotthard tunnel is 49,016′ long; straight, with the exception of a curve at the southern end 636′ long. The up-grade from the north portal to the center of the tunnel is 30.7′ per mile; then a length of 1,046.3′ is horizontal, elevation 3,786.76′ above sea; and the down-grade to the southern portal is at first 2.64′, then 10.56′, and then 5.28′ per mile. The cross-section of the tunnel is for a double track 26.28′ wide, 19.68′ high—441 square feet area of clear space. The entire tunnel is lined with masonry in slow-binding hydraulic mortar; the arches vary in thickness from 14″ to 28″. The advance header was located in the highest part of the cross-section; it was forced ahead of all other work. Some distance behind it the lateral enlargement was made, still further back, a bottom cut was made in two or three steps, and from there the remaining part was excavated. The two advance headers met February 29, 1880, seven years and four months after its commencement; twenty-two months afterwards the tunnel was completed (December, 1881). The system of constructing the tunnel was the Belgian system, the arch being built immediately after the upper lateral enlargements are finished, and the abutments after the full connection has been excavated. The temperature of rock in the centre of tunnel and 5,580′ below the surface, was 88° F.—the outside temperature being 21°. The air temperature was several degrees higher than the rock temperature, caused by the

working, lights, and gases derived from explosives. The rock traversed was gneiss, gneissic-granite, amphibol, serpentine, black slate and micaceous slate; it was generally quite solid, and only in three places of an aggregate length of 1,083′ the ground was swelling. The section below the Andermatt plain —about 1¾ miles from the north portal—295′ long, was exceedingly difficult. It was swelling, the rock being caolin, gypsum and anhydrite. The masonry was reconstructed three times; the arch is now 4′3″ and 4′11″ thick at the key, and from 6′7″ to 8′7″ in the line of the scewbacks. (The cost of lining the tunnel with masonry was $2,680,000; the total cost of constructing the tunnel was $11,120,000.)

Southern Mountain Division.—Having passed the Gotthard tunnel and the station Airolo, situated 82′ above the bottom of the river Ticino, the road occupies the left slope of the valley down to the gorge of Stalvedro, then crosses the river upon a bridge, 164′ span and 33′ above water level, and follows now the right-hand slope with a grade of 132′ per mile to Ambri sopra, where the grade changes to 26.4′ per mile, down to station Fiesso (elevation, 3,080′). Then the first cataract of the Ticino valley, the gorge of Dazio, is encountered; the same is very wild; the river falls with a grade of 316′ to 528′ per mile. The length necessary to overcome this steep section and the one immediately below, was obtained by an artificial development (Fig. 6), necessitating two long circular tunnels, five shorter tunnels, and three bridges across the Ticino (147.5′, 98.5′ and 213.5′ span). At the end of this development the railroad is 305′ lower than at the beginning. The circular tunnel of Freggio, 5,130′ long, passes through gneiss, rich in quartz, while the rock through which the circular tunnel of Prato, 5,102′ long, passes, is gneissic-micaceous slate. The grade in both tunnels is 121′ per mile, and the curves are 5°50′. They were worked by percussion drills and top-header (65 to 100 square feet) from the lower mouth upward, and by hand labor from the upper entrance. The monthly progress made in the headers varied between 148′ and 230′ by machine drilling, and from 65′ to 99′ by hand drilling. Below the last circular tunnel the road recrosses the Ticino on a bridge of 213.5′ span (iron-weight, 265 tons);

the station Faido is reached, at an elevation of 885′ above the bottom of the valley, and 2,345′ above sea level.

From Faido to Lavorgo the railroad runs near the stage road on the left side of the valley. Between Lavorgo and Giornico the last cataract, the Biaschina, has to be overcome. The grade of the river is 610′ per mile. An artificial development (Fig. 6[a]) is again necessary, 2.35 miles long, including two circular tunnels, which are very near each other horizontally; the Piano-Tondo tunnel is 4,945′ long, and the Travi tunnel 5,070′ long. The grade in both tunnels is 121′ per mile, and the curves are of 5° 50′. The rock encountered is solid gneiss, rich in quartz and feldspar. The top-headers were driven by percussion drills from the lower entrances; average cross-section of header 54 to 65 square feet; monthly progress in each header varied from 164′ to 197′. The advance headers from the upper entrance were driven partly by hand labor, partly by machine drilling. Like all other circular tunnels, these were also built for double track, and are lined with masonry for nearly their entire length. This section belongs to one of the most difficult of the Gotthard railroad; the mountain slopes are very steep; numerous tributaries are crossed (Piano-Tondo creek viaduct, four spans of 84.4′, weight of iron, 140 tons each span; Travi creek viaduct, 3 spans of 65.7′, weight of iron 68.5 tons each span; the piers are of masonry. Having passed out of the Travi tunnel, the road crosses the Ticino and runs into the station Giornico, below which it recrosses the river and now remains on the left side of the valley. After having crossed the wild torrent Vallone at Bodio on a bridge of 91.5′ span, and the Brenno river on a viaduct of two spans of 115′ each, and two spans of 164′ each, it reaches the station Biasca. Here the mountain division ends. The line below Biasca is comparatively easy. It was finished all ready in 1874 to Belliazona, Cadenazzo and Locarno.

Mont Cenere Branch Line.—At Giubiasco, a station below Bellinzona, the Monte Cenere line branches off. It ascends the mountains with a grade of 137′ per mile. The slopes are densely covered with chestnut trees. The line crosses numerous gorges on high and long viaducts, and passes through several short tunnels, until it reaches the Mont Cenere. Among the largest

viaducts are that of Selvaccia (iron girders, 131′ span, weight 102 tons), that of Bobasacco (164′ span, weight 149 tons), and that of Piantorino seven stone arches of 39.4′ span, highest piers 98.5′ high. The Monte Cenere is a divide between the Ticino and the Vedeggio. It is crossed by a tunnel 5,498′ long, the grade being continuously ascending with 117.5′ per mile; rock traversed gneiss and micaceous slate; top-advance header was driven by four percussion drills; average monthly progress 394′. The descending header from the other mouth was driven by hand labor; average monthly progress 115′. This tunnel was finished in two years and three months. The highest point of this branch road is at Bironico, 1,538′ above sea level. The line then follows the valley of the Leguana and Vedeggio rivers, which offer easy ground for a railroad. Maximum grade from Monte Cenere tunnel to Lugano is 111′ per mile. Before reaching the station at Lugano, the Massagno tunnel, 3,030′ long, is traversed. At Lugano, connection is made with the railroad to Chiasso at the Italian-Swiss boundary, already built in 1874. This branch of the Gotthard railroad serves the direct traffic to Milano. The main line of the Gotthard line runs south of Cadenazzo, along the east shore of the Lago maggiore, making connection with the Italian railroad at Dirinella.

Principles of Construction.—The width of the single track roadbed, measured on a level with the upper surface of the ties, is 13.8′ in the mountain divisions, and 13.1′ in the valley divisions. The embankments are usually made of rocky material, and have slopes of $1\frac{1}{4} : 1$; if no fertile earth was obtainable, the slopes were covered with a layer of hand laid rocks, 2′ thick. (Figs. 7, 8^a, 8^b and 9) When steeper slopes were necessary, the slopes were made of rip-rap, 1 : 1, up to a height of 65′, (Fig. 10) and of dry masonry, with a slope of $\frac{2}{3} : 1$, if the embankments were not higher than 33′ (Fig. 11). Retaining walls of masonry in mortar were either built with an outer slope of $\frac{1}{5} : 1$ or vertical; if high, loose rocks were packed in back of them (Figs. 12, 16, 18) Retaining walls with arches and buttresses were used, where the foundation was difficult and the ground was solid only on isolated places. The buttresses having very little effect, as they do not protrude very far beyond the outer face of the

wall, this kind of walls was abandoned, and used but once near Amsteg (Fig. 18[a]). Cuts were made with either 1 : 1 or 1.5 : 1 slopes (Figs. 8 and 9) or vertical in solid rock; in this case the lateral ditches were widened to protect the road from falling rocks. In regions of heavy snowfall, ditches from 6′—10′ deep and wide were dug. Retaining walls in cuts are mostly built of masonry in mortar, rarely of dry masonry (Figs. 13, 14 and 15). Protection of the slopes against the river current was either obtained by pavement with a slope of 1.5 : 1, or by rip-rap with 1 : 1 slope. In front of these are loose stones piled up to high-water mark, and with a berm 6′ feet wide. (Figs. 17 and 17[a])

The tunnels on the valley divisions were built for one track; in the mountain divisions for two tracks. The portals of the tunnels are built in a very unpretentious manner; in loose, sliding ground they were strengthened by strong buttresses.

Culverts are mostly made of arches in masonry, their bottom having an continuous grade; when very steep, the lower part is supported by heavy buttresses. (Figs. 20 and 20[a])

Where avalanches and torrents had to be passed under, strong and capacious aqueducts were built. Viaducts were used to cross rivers and on steep slopes where sustaining walls would be too expensive; the arches vary from 26 to 40′ span. Larger viaducts were built of iron girders with stone piers.

The iron bridges are of the usual European construction. The track-ties are all creosoted. The rails are of steel, 74 lbs per yard. The gravel bed is from 1.3′ to 1.64′ thick. The stations are from 3 to 5 miles apart. The rolling stock consisted at the time of opening of the road to commerce of 61 locomotives, 127 passenger cars, lighted by gas, and 538 freight cars.

Contracts.—The road was built in several sections by different contractors, they being paid by the unit of quantities. The bids were from 7 to 23 per cent. below the company's estimate, and still all the contractors—except L. Favre, of the great tunnel—made money.

Proportional Length of Tunnels.—On the entire line of the Gotthard Railroad are 56 tunnels. On the mountain division alone, 56 miles long, are 31 tunnels, not counting the galleries;

their aggregate length is 18.6 miles, or 33 per cent. of the total length. The proportional length of tunnels to the length of the single divisions is as follows:

Division.	Length of Division.	Length of Tunnels in per cent. of the length of Division.
Brunnen-Fluelen	6.75 miles.	49 per cent.
Erstfeld-Pfaffensprung...	10.00 "	20 "
Pfaffensprung-Gœschenn.	7.25 "	38 "
Fiesso-Lavorgo	8.50 "	33 "
Lavorgo-Biasca	10 00 "	27.5 "
Giubiasco-Lugano.....	15.00 "	13.5 "

47 per cent. of the total length of the road are in curves and 80.4 per cent. on grades.

Operation of the Road.—From Immensee to Erstfeld and from Biasco to Dirinella no steeper grades than 52.8′ per mile occur. Here heavier trains can be operated by lighter locomotives. From Erstfeld to Biasca the grades vary from 132 to 143′ per mile. There much lighter trains require heavy engines. The freight engines are 6 and 8 wheelers, weighing, when in service, 43 resp. 54 tons. They move 380 resp. 500 tons on the valley divisions, but only 140 resp. 170 tons onthe mountain divisions. A freight engine of the valley division serves as passenger engine on the mountain division; a freight train requiring one engine in the valley requires two engines in the mountains. The Gotthard Railroad was opened for traffic on June 1st, 1882.

The maintenance and operation of the Gotthard Railroad is under the control of the Swiss government, which guarantees to secure the travel against all interruption, elementary causes excepted, and to keep the road in such order that it can satisfy the demands of the heaviest international traffic. The neutrality of the road in case of war is guaranteed.

The Gotthard Railroad is the grandest railroad in Europe. Its location is excellent in every respect; its construction is correct and based on the latest experiences. Improvements will certainly become necessary in the course of years, as it is next to impossibility to foresee all emergencies in such a mountainous country.

Arlberg Railroad. — The latest Alpine railroad is the Arlberg Railroad, connecting Austria with Switzerland. It connects Innsbruck, terminus of the Brenner Railroad, with Bludenz, the terminus of a railroad to Bregenz on the eastern end of the Lake of Constance. From Innsbruck to Landeck, 45.9 miles long, the railroad follows the valley of the river Inn, from Landeck to St. Anton, 16.1 miles long, the valley of the Rosana, a tributary of the Inn, from St. Anton to Langen, 6.16 miles long, underground through the Arlberg, and finally from Langen to Bludenz, 16.1 miles long, along the Kloster valley, being a branch of the Alfenz, a tributary to the Rhine. The line runs from east to west. From Innsbruck to Landeck it uses the south side of the valley, being nowhere more than 65.5′ above high water; from Landeck to Pettneu it follows also the south side, and from there to the east entrance of the main tunnel the north side; from Landeck for a length of 4.34 miles the line is 131′ above the bottom of the valley, and at Wiesberg 236′, which is the maximum. The line from Langen to Bludenz runs along the northern side, and is for a length of 9.3 miles 131′, in maximum 426′ above the bottom of the Alfenz valley. The elevation of Innsbruck is 1,903′, that of Landeck 2,550′; St. Anton, 4,260′; Langen, 4,230′, and Bludenz, 1,831′. The highest elevation of the road is in the main tunnel, 4,299′ above sea. The sharpest curve in the section Innsbruck-Landeck is $5\frac{3}{4}°$, and the maximum grade 46.5′ per mile, which is reduced in curves proportionally, it being 30.6′ per mile in a $5\frac{3}{4}°$ curve. The sharpest curve in the section Landeck-Bludenz is 7°; maximum grade on tangents, 137.2′ per mile, and in the sharpest curves 123.5′ per mile in the section east of the Arlberg tunnel; west of the Arlberg tunnel, from Langen to Dalfaas, on tangent, 161′ per mile, and in sharpest curves 145′, and from Dalfaas to Bludenz 165.8′ resp. 150′ per mile. (Fig. 21.)

The road is built for a single track, with the exception of the Arlberg tunnel. The width of the roadbed is 17′. The dimensions of arched culverts and retaining walls are about the same as those of the Gotthard Railroad. Dry masonry is used very extensively, cut stone is used only where heavy pressure occurs; otherwise rubble work, more or less ranged and laid in hydraulic

mortar is employed. The same is used also in the lining of the Arlberg tunnel, and for the piers of viaducts and abutments of bridges, as well as arches of less than 200′ span.

Arlberg Tunnel.—The principal structure of this road is the Arlberg tunnel. The same is 33,587′ or 6.35 miles long. The eastern entrance is 4,271.9′ above the level, and the western curve 3,991.2′, while the highest point in the tunnel is 4,298.8′. The grade from the east portal is 10.56′ (13,448′ long), and from the west portal 79 4′ per mile (20,139′.) The tunnel is 19.65° high and 26.2′ wide in the clear; the arch has a radius of 13.1′; the abutments are formed as segments of circles with 33.1′ radius, and the invert with 19.4′ radius. The size of the excavation varied according to the nature of the rock and the thickness of masonry required. The rock traversed was principally micaceous slate rich in quartz and gneiss. Layers of clay and graphitic beds occurred in the west side, and were very troublesome, interfering considerably with the machine drilling. The advance header was located in the lowest part of the final cross-section, 8 25′ high and 9′ wide in the clear; every 210′ back of the face upraises, with an area of 32-44 square feet were made up to the high est point of the tunnel; from these top-headers (8.25′ high and 6.6′ wide) were driven to both sides. After these top-headers were connected with each other the lateral and lower enlargements were made. This system was carried out with great regularity and made a rapid completion of the tunnel possible. Its success depends principally upon the rapid advance of the bottom header. This was forced with all possible means. The east header was driven by percussion drills (system Ferroux) worked by compressed air. From six to eight drills were used on one carriage. The chisel-shaped drill is varied from 1″ to 1¼″ in diameter, with the edges from 1½″ to 2″ wide. The pipe carrying the compressed air to the drills was 16″ in diameter. The number of holes on the face was in the first half mile 15 to 25, then it varied between 25 and 35, which were fired in three different sections. In an average 3.5 drilling attacks were made in 24 hours. The pressure of the compressed air varied from 60 to 90 pounds per square inch.

The west header was driven by the hydraulic rotary drill, system Brandt, which is worked by water under high pressure, varying from 1,200 to 1,500 pounds per square inch, being carried to it in 3″ and $2\frac{3}{4}$″ pipes. The drill bit is pressed against and into the rock by quiet hydraulic pressure, and is slowly rotated. The drill bit is annular, with an outer diameter of $2\frac{1}{2}$″, and an inner diameter of $1\frac{21}{32}$″; it has four teeth about $\frac{13}{32}$″ high, which are bent a little outward, so that the drill-hole is $2\frac{3}{4}$″ wide. The drill works perfectly quiet and noiseless. From 8 to 16 holes were needed for each attack. At first two machines on one column were used, later, three, and in the last year, four. Very few repairs were required; one machine drilled on an average 6,500′ of holes before it was taken out of the tunnel for repairs.*

The plants on both sides were driven by water-power. The construction of the Alberg tunnel is an important step in advance in tunneling; it has been carried out in a systematic manner, and was completed more rapidly than the most sanguine engineers expected. The average daily progress of the advance header (including four months hand labor) was, on the east side, 14.4′, and on the west side, 12.60′; leaving out hand labor, the progress was 16.50′ resp. 14.20′. The largest monthly progress of the last year of construction was 1,080′, both headers together, while the absolutely largest progress was 1,250′, or 41.7′ per day. The drifting of the advance headers (33,587′) took 40.5 months, while that of the Mont Cenis tunnel (40,124′) occupied 160, and that of the Gotthard tunnel (48,938′) 87.75 months. The respective monthly total progress was, in the Mont Cenis, 251′, Gotthard, 558′, and Arlberg, 830′. Comparing the last years of construction only, the average daily progress was, in Mont Cenis, 13.1′, Gotthard, 22.3′, and Arlberg, 35.5.

Other Alpine Roads Proposed. — The principal object of the Alpine roads—running north to south—is to satisfy the international commerce between northern Europe and the Orient and East India. Their objective point is the city of Piacenza, in upper Italy, where communication is made with the road to

*—A detailed description of the Brandt drill and the Arlberg tunnel, was published by the author in *Mining and Scientific Press*, 1884. Nos. 17–20.

Brindisi, the great shipping point on the Adriatic Sea. The Gotthard railroad is the most direct road, and has the largest traffic; it has proved to be a most powerful competitor to the Mont Cenis railroad. This is the reason that numerous new railroads across the Alps are proposed, as across the Simplon (Brieg-Domo d'Ossola), Mont Blanc (Geneva-Aosta), Great St. Bernard (Martigny-Aosta), Little St. Bernard (Albertille-Aosta), Mont Genévre (Chur-Briançon), Col di Tenda (Cuneo-Nizza), and Spluegen (Chur-Chiascuna).

The first two of these projected lines have created a great deal of interest and discussion, as either of them would return to France and Western Switzerland a part of the traffic drawn by the Gotthard railroad from the Mont Cenis. One of these two roads is more likely to be built than any of the others.

The first proposition to build a Simplon railroad was made in 1852. Since then to the present time ten different lines have been proposed, of which that of Mr. Lommel and that of Mr. Meyer are the best.

Propositions for the Mont Blanc railroad were made in 1857 by Alby and Borrelli; in 1874 by the Belgian engineer, Stamn; and recently by the Italian engineer Barretti, and the French engineer Mury.

It is evident that the Simplon railroad cannot be built without a French subsidy, although it does not run through French territory. In November, 1880, the representative Renault proposed to the French government to grant to the Simplon railroad an annual subvention of $1,000,000, for a period of ten years. A committee was appointed to examine the Simplon railroad and any other proposed line, especially the Mont Blanc, in their relation to French interests. The commission reported in July, 1881, against the Simplon line, because of the steep grades on the south side of the Simplon and the unfavorable grades of the Jura railroad from Dôle to Lausanne. This railroad is the natural outlet of the Simplon line, and is already in operation. Further objections were, that the Simplon line does not traverse French territory, and that the commerce of Marseilles would be curtailed in favor of Geneva. The fears about the damaging effect of the Gotthard railroad upon French commerce have been proven to

be correct. Italy has commenced to supply its demands from Germany instead of France, as formerly. German merchants and manufacturers have established agencies all over Italy, and the number of Italian travelers in Germany is constantly increasing. The annual traffic of the Gotthard railroad was estimated to be 250,000 passengers and 350,000 tons freight; the annual traffic from July 1, 1882, to same date, 1883, was 950,000 passengers and 400,000 tons freight, which yielded a net income of $13,550 per mile. The traffic of the Mont Cenis and the Paris-Lyon-Mediterranean railroad decreased proportionally.

The proposed Simplon line has been studied very carefully. Lommel's project of 1878 has been superseded in 1882 by one of Mr. Meyer. The line commences at the station Brieg, the present terminus of the Rhone Valley railroad. A short distance from this station is the northern entrance to the main tunnel, at an elevation of 2,260′ above sea level. The length of the tunnel is 12.4 miles; the ascending grade in the north half is 10.56′, and the descending grade in the south half is 42.24′ per mile. The southern entrance of the tunnel is located near the village of Isell, 2,060′ above sea; the line then follows the right shore of the river Diveria within a short distance of Domo d'Ossola; then it runs along the right shore of the river Toce with a long development curve in the Bogna valley. The maximum grade is 66′ per mile. At Piedimulera, 806′ above sea level, the line reaches the bottom of the valley, and connects with the railroad to be built by the Italian government from Gozzano to Domo d'Ossola. The length of the proposed road is 33.4 miles, the southern descent alone being 20 miles long. The cost is estimated at $21,000,000. The main tunnel will traverse the mountain chain of Monte Leone about 1.85 miles to the north of the highest peak (11,700′ high) in a broken line, so as to avoid the highest mountains, which would tend to raise the temperature considerably higher. This broken line will allow the sinking of two air-shafts. The highest elevation passed under by the tunnel is 9020′ above sea level, therefore the height above the tunnel level is 6,740′, which gives a probable air temperature in the tunnel of 95° F., a temperature of over 86° F. to be expected to prevail for a distance of 8 miles. The rock to be traversed (commencing from the north entrance) is gray slate (Trias), then

about 5.6 miles crystalized slate, and the last 4.34 miles antigoric-gneiss with micaceous slate underlying. The stratification is favorable for drilling and blasting; no heavy swelling ground nor much water will be encountered. None of the proposed locations of the Simplon tunnel, although a little shorter and straight, offer as many advantages in reference to temperature and geological conditions as Meyer's plan. The two shafts shall be sunk on an incline, one about 4 miles from the north portal, 3,280′ deep, and the other about 3.25 miles from the south portal, 2,230′ deep. It seems to be advisable to sink these two shafts in spite of their great depth, as they will facilitate greatly the ventilation during construction; their cost is estimated at $400,000. The machinery necessary for building the tunnel will be driven by water power, 8,000 horse power being available on the north side, and 4,000 on the south side. The cost of the plant is estimated at $1,500,000. In 1876, the first triangulation to ascertain the exact length of the proposed tunnel was made; a base line was measured on either side, being 10,574.72′ respectively 10,407.44 long. The points of the 23 triangles were all at very high elevations (max. 10,650′), which made the triangulations very difficult. The cost of constructing the tunnel is estimated at $14,500,000, or $221 per running foot. It will require seven years.

The cost of constructing the southern line connecting the tunnel with the Italian railroad is estimated at $5,900,000, or $302,-564 per mile. The northern connecting lines are the two Swiss railroads running from Brieg to Lausanne and Vallerbes (117.75 miles) and the French railroad from Vallerbes to Pontarlier and Dijon (102.3 miles). These lines have steep counter-grades (from 121.4′ to 132′ per mile), which fact was used by the French Commissioners as an argument against the Simplon railroad. These grades can be altered to a maximum of 71.25′ per mile at an expense of $5,400,000.

Mont Blanc Railroad. — The Mont Blanc line has not been studied so carefully as the Simplon line. The preliminary line starts from Annemasse near Geneva (1,418′ above sea), runs along the River Arve with a grade of 66′ per mile to Taconnaz (3,440′ above sea), near Chamounix, 52.7 miles long. There the main

tunnel commences. It is 11.9 miles long; its southern entrance is near Pré St. Didier (3,442′ above sea). From there the line descends with a maximum grade of 71.4′ per mile the narrow valley of the Dora Baltea, 23.6 miles long to Aosta (1,900′ above sea), connecting there with a road to be built by the Italian government. The total length of the Mont Blanc Railroad is 88.7 miles; the cost of construction is estimated at $30,750,000. The tunnel is straight, crosses the mountain chain north of Mont Blanc (15,700′ high) and south of the Col du Géant (13,100′) and about directly under the Mont Blanc du Tacul (13,100′). The greatest height of the mountains above the tunnel will be about 9,850′; therefore the temperature to be expected in the tunnel is 126° F., with 86° for more than five miles.

The geological features of the Mont Blanc tunnel are: Jura formation of chamounix, crystallinic slate, protogia, standing in vertical, fan-shaped layers (3.75 miles long), Jura formation of Vallée blanche, and last 3.4 miles gypsum, dolomite and anhydrite. In the last 3½ miles the tunnel is only from 650 to 850′ below the surface, running under the main valley and many cross valleys. The construction of the central section of the tunnel will be exceedingly difficult on account of the high temperature, although the geological formation is favorable. The formation of the southern end is very unfavorable, as the gypsum and anhydrite will swell and the moist dolomite will admit large quantities of water into the tunnel. It may also occur that the mineral springs of Commayon, la Saxe and Dollone may disappear, being drained through the tunnel. It is proposed to sink three inclined shafts in this section, which may be impossible to do on account of the unfavorable ground. Water power is obtainable on both sides. The cost of the tunnel is estimated at $14,000,000, or $222.80 per lineal foot.

It is evident that the construction of the proposed tunnels offer the greatest difficulties, especially on account of the high underground temperature to be expected. It is therefore of special interest to ascertain the probable temperature in the two tunnels.

Underground Temperatures.—The temperature in underground works is not only dependent upon the depth of the work below the surface, but also upon the surface temperature, upon the height of the surrounding masses of rock, the capacity of the rock to transfer heat and its state of decomposition, also upon the presence of cold or warm springs. It may be assumed that under perfectly normal conditions the temperature increases 1° centigrade with each 30 meters, or 1° Fahrenheit with every 55′. This proportion, however, may vary considerably.

The highest temperature in the Mont Cenis Tunnel was 85° F. at a maximum height of rock above the tunnel of 5,250′, lasting for a length of 1,640′ only. The highest rock temperature observed in the Gotthard Tunnel was 88° under 5,640′ of rock, which corresponded to an air temperature of 88°–92°. The proportional increase of temperature was in both cases 1° F. for every 91 resp. 100° (1° C. for every 50 resp. 55 metres). Formulæ have been established by Mr. F. M. Stapff, formerly chief geologist of the Gotthard Tunnel, based on observations made in the Gotthard Tunnel, by which the temperature to be expected at a given depth can be found. As the conditions of the Simplon and Mont Blanc are very similar to those of the Gotthard and of other tunnels in the Alps, these formulæ have been applied to them. They give the probable temperature in the Simplon at 95° (35° C.) and at the Mont Blanc at 126° (52° C.).

The high temperature of the air during the construction of the Mont Cenis, and much more yet of the Gotthard Tunnel, was very obstructive to progress. In the latter the men suffered from impoverished blood, many also from worms in their bowels, the worms being similar to those observed in tropical countries. About 60 per cent. of the laborers suffered from impoverished blood; many of them died later in the hospitals at Turin and Milano. The high temperature, the very moist air, vitiated with obnoxious gases, were the causes of the immense number of sick men during the last year of the construction of the Gotthard Tunnel. According to Stockalper, former chief engineer of the tunnel contractor, the bad influence of the underground air upon the health of the men commenced as soon as the temperature of rock was higher than 84°. This occurred in the north header, at a

distance of 2.8 miles from the north portal, and in the south header, at 3.4 miles from the south portal. In some parts of the work—lateral enlargements—the air temperature was as high as 91° and 95° (32.5° and 35° C.), which, in connection with the large percentage of moisture, caused invariably sickness. The working hours were reduced from seven to five hours, and the wages were raised. Professor du Raymond says that a man can work in a temperature of 122° (50° C.) if the air is perfectly dry, but if the air is filled with aqueous vapors it is impossible to work longer than a few minutes at 104° (40° C.).

The observations about underground temperatures made at the Gotthard tunnel and more recently at the Arlberg tunnel, have furnished important facts to the solution of this question. The same is of sufficient interest to deserve a treatment more detailed than it can be given in this paper. Only a few facts are given, leaving a more exhaustive treatment to a future communication.

The experiences of Reich in the mines of Saxony, and those of Dunker in the drill-holes at Sperenberg, establish the fact—not considering peculiar local influences not yet well understood—that the ground temperature under not very high mountains increases 3° C. with every 100 metres (in round figures, 5° F. for each 300′). Sir William Thomson arrives at nearly the same conclusion by calculation, and gives the increase at 1° F. for each 50′.

The observations made at the Mont Cenis tunnel cannot well be used in the solution of the question of underground temperatures, as they were made only on the south side, where the temperatures were modified by the neighborhood of the Merdovino valley. Only fifteen observations of the temperature of air, rock and water were made, all between 1,200 and 24,000′ from the southern portal.

The Gotthard observations have been made with the greatest care, and in accordance with the most approved scientific methods. Dr. Stapff, the geologist, calculated that the temperature in the central part of the Gotthard tunnel would be 31.74° C., with a probable error of 2.55° one way or the other, while it actually was 30.43° C.

In such large underground works as the Alpine tunnels, special provisions must be made to cool the body of the laborer at frequent intervals; to furnish cool air by shafts, to produce a lively current of the air, to absorb rapidly the perspiration from the naked bodies of the laborers, and to drive out the bad gases. The oil and candle lamps should be replaced by electric lamps; the gases of the explosives should be rapidly condensed (which was done successfully at the Pfaffenspung, Sonstein and Arlberg tunnels by a spray of water issued under considerable pressure immediately after the blasts were fired. This improvement was first made in connection with the Brandt hydraulic rock drill). Locomotives driven by compressed air or electricity should be used; human labor should be replaced whenever possible by mechanical appliances. It is most important to keep the air dry; the water, not in the underground works, must be led away rapidly in closed viaducts; eventually, moisture-absorbing substances should be used. How important this fact is, was proven to the writer by observations in the Sutro tunnel. The average temperature of the air in the face was 92°; the men worked stripped to the waist. Fresh air was delivered to the working places from a blower stationed at the junction with the main shaft, the same being a down-cast, through a 11″ galvanized iron pipe. When a man desired to cool off he quit work for a few minutes and stood before the air pipe; he felt at once cooled and refreshed, until his body was perfectly dry and free from perspiration. The temperature of the air running from the pipe was from 2° to 3° higher than that of the air in which the men worked, but was dry in comparison to that air. The evaporation of the sweat and the consequent opening of the pores in the skin relieved the man of the oppressive feeling which he experienced while in the moist air at the working place.

The observations of rock-temperatures in the Arlberg tunnel were made in this way: In dry ground of the advance header, a hole 2.6′ deep was drilled; it was left open for one day, then a thermometer 10.½″ long was inserted, the quicksilver bulb being surrounded by oil. The hole was then closed with waste and left undisturbed for 24 hours. A few of the observations made are :

Distance from Portal.	Height of Mountain above Tunnel.	Temperature		Increase for each 300′.
		Air.	Rock.	
feet.	feet.	degree	Fahrenheit.	
984	328	48.2	48.0	
3,280	656	53.4	53.2	4.75
4,757	984	56.3	54.5	1.19
5,413	1,312	58.1	55.4	0.82
6,234	1,640	58.1	55.9	0.46
7,706	1,969	62.6	60.3	0.40
9,187	1,969	64.4	61.9	1.46
10,171	1,640	63.5	60.8	1.01
12,796	1,640	63.0	59.2	1.42
13,452	1.969	65.1	60.8	1.46
14,764	2,297	66.6	62.8	1.83
16,569	2,297	68.0	65.1	2.10

These temperatures are not mean temperatures, but those observed at that particular place and line. The highest air temperature in these bottom headers was 7.2° higher than the rock temperature at the same place and time. In other places of the tunnel (lateral enlargements, etc.) the temperature was still higher. The maximum of 77° was observed in the lateral enlargement at 8,850′, the minimum of 63° at the top enlargement at 7,850′. The maximum temperature in the header was 72½°, minimum 56½°.

Comparison between the Simplon and Mont Blanc Railroads.—In considering the two proposed railroads—the Simplon and the Mont Blanc roads—the first one is the most favorable, as the temperature to be expected in the summit tunnel is 17° lower than in the Mont Blanc, and as the two shafts proposed will shorten the central section of the tunnel to about 5 miles, and will facilitate ventilation. A good stage road leads across the Simplon, being of great assistance during the preliminary work and the time of construction. There is no road across the Mont Blanc. The cost of building the Simplon railroad is less than that of the Mont Blanc line. The Simplon tunnel is located at a lower elevation. The Simplon railroad will be more effective as an opposition to the Gothard railroad, as it enters Italy in a district at present controlled by the former. The Mont Blanc road is too far from the Gotthard and will rather take traffic away from the Mont Cenis. Piacenza is the objective place of all the Alpine railroads, the distances from the nearest Atlantic harbor to that point over the different routes are (See table III):

TABLE III.

NAME OF RAILROAD.	NORTHERN DIVISION.					TUNNEL.			SOUTHERN DIVISION.				
	Termini Name.	Elevation of Termini.	Length.	Max. Grade.	Cost.	Length	Max. Grade.	Cost.	Termini Name.	Elevation of Termini.	Length.	Max. Grade.	Cost.
		feet.	miles.	feet per mile.	million dollars	miles.	feet per mile.	million dollars		feet.	miles.	feet per mile.	million dollars
SIMPLON.													
Brieg-Piedimulera, Length, 36.2 miles, Cost, $21,000,000.	Brieg, Northern entrance to tunnel.	2,222 2,260	0.93	40.7	0.5	12.4	42.25	14.5	Southern entrance to tunnel, (Iselle) Piedimulera.	2,050 807	20	66	5.9
MONT BLANC.													
Annemasse-Aosta, Length, 88.2 miles, Cost, $30,750,000.	Annemasse, Northern entrance to tunnel.	1,418 3,442	52.7	66	12	11.9	10.55	14	Pré St. Didier (Southern end of tunnel) Aosta.	3,442 1,900	23.6	71.4	7.2

Black Forest Railroad.—Another interesting mountain railroad is the Black Forest railroad. The Black Forest is not a part of the Alps. It is situated in the southwestern part of Germany. The mountain division of this railroad from Hornberg to St. Georgen, is 17.8 miles long. There are 34 tunnels with an aggregate length of 5.15 miles. The sharpest curve is 5° 50′, and the maximum grade 106′ per mile. This road is an interesting example of developing a line by turning back twice (Figs. 22 and 23).

The sources used for the above compilations are:

Prof. Dolezalek, Die Gotthardbahn; published in the transactions of the Hannoverian Society of Architects and Engineers, 1882.

Prof. Dolezalek, Die Simplon and Mont Blanc Eisenbahn. A paper read before the Hannoverian Society of Architects and Engineers, 1884.

Prof. Scheidtenberger. Der Arlberg Tunnel. A paper read before the Polytechnic Club of Graz.

Numerous official documents and private notes.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME II — AUGUST, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

August 7, 1885.

President Mendell in the Chair.

Messrs. Tashiera and Hanscom were appointed tellers to count the ballots, and Frank Soule, Jr., was declared elected a member, and P. J. Van Löben Sels an associate.

L. J. Le Conte read a paper entitled "Are not Dynamite Catastrophes intimately associated with Electric Phenomena?"

Mr. Specht narrated the experience at the Sutro Tunnel, where unusual electrical phenomena were manifest during the dry weather, and the blaster was obliged to discharge the electricity in his body before preparing the cartridges for blasting.

Mr. Hoadley told of certain remarkable electrical phenomena observed by him.

Mr. Vischer inquired if Mr. Le Conte had investigated the causes producing the explosion—if the explosion was a primary or a secondary phenomena.

Mr. Burrell stated that his experience at the sugar refinery was that finely pulverized sugar in the pulverizer room was free

from explosion, although all the conditions for dust explosions were present, and suggested that it might be due to the absence of nitrogen.

Mr. Le Conte thought there might be sufficient moisture in the sugar to prevent explosion.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME II — SEPTEMBER, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

September 5, 1885.

Vice-President Specht in the Chair.

The following propositions for membership were read:

John P. F. Kuhlman, proposed by Geo. J. Specht, G. W. Percy and J. C. Henkenius.

W. B. Sherwood, proposed by J. D. Schuyler, Harold Wheeler and L. Wagoner.

Mr. Geo. J. Specht read a paper on "The Location and Construction of the Railroads across the Alps."

The Committee on Discussion presented the following report, which was adopted:

The Committee appointed July 10, 1885, has agreed upon the following resolutions:

WHEREAS, The usefulness of the Society to its members will be widened if subjects are presented for discussion at the meetings without the previous reading of a formal paper, such discussion to be reported, and if approved by the Executive Committee, to be published in the Transactions; and as many topics of general interest and value do not admit of a paper being prepared about them, and many of the members best informed on special topics cannot be induced to write a paper on any of them, be it

Resolved, That a Standing Committee of three be appointed by the President to prepare topics and procure and present questions for discussion at the meetings of the Society, without the formal necessity of a previous paper.

Resolved, That the presentation and discussion of such topics, as may be approved by the Committee, be made a regular feature of the meetings.

The undersigned Committee urges all the members to co-operate with them by suggesting any questions or topics which may occur to them as suitable for discussion, especially such as are likely to elicit valuable facts of experience or practical data.

The Committee has adopted the following rules for the execution of the business entrusted to them:

1. Questions or topics proposed to be discussed must be submitted to the Committee at least forty-five days before the meeting at which the discussion shall take place. The proposing member should state not only the general object, but should itemize the main points of the question. It will facilitate the business of the Committee if the names and addresses of those members which are known to the proposer to be well informed about the question, were mentioned in the proposition.

2. The Committee shall then prepare the proposed question in such a manner as it thinks most suitable to develop an extensive discussion. The prepared questions shall then be printed and sent to each member of the Society thirty days before the date of the meeting, with the request to prepare themselves for the discussion. Opinions can be sent in writing.

3. The discussion shall be reported in short-hand, and before printed shall be sent to the members who took part in the discussion, with the request to correct mistakes and to add whatever may seem apt to contribute to the value of the discussion, even if not mentioned at the meeting.

As this proposed innovation is as yet an experiment, the Committee request all members to make any suggestions which they think may improve the mode and manner recommended by the Committee.

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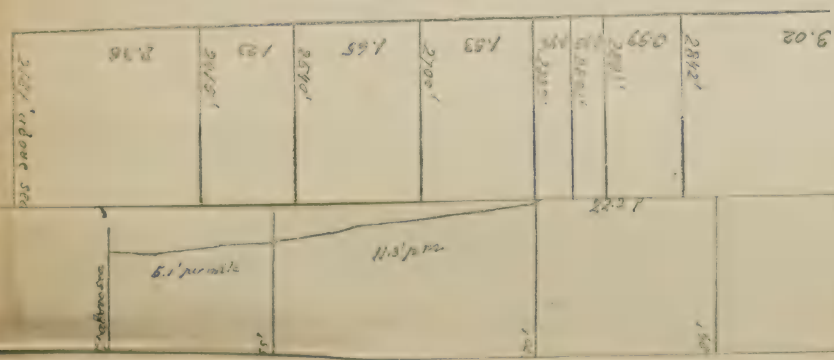
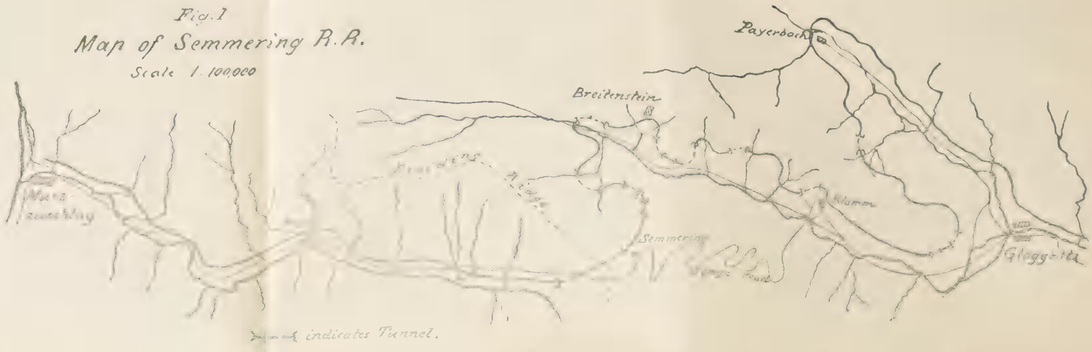


Fig. 1
Map of Semmering R.R.
Scale 1. 100.000



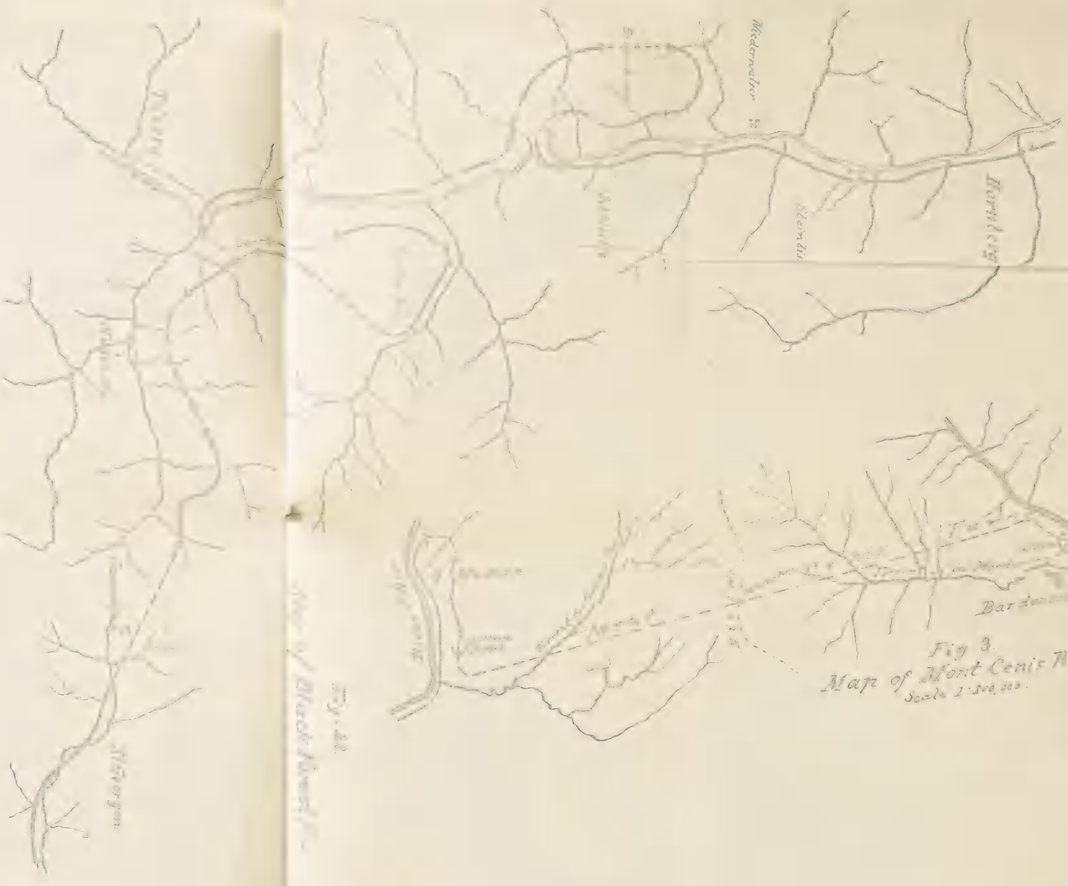


Fig. 3.
Map of Mont Cenis R.R.
Scale 1:500.000.

Fig. R3.
Black Forest R.R.

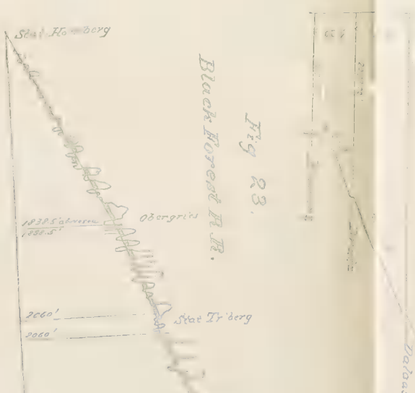


Fig. R1.
Arlberg R.R.

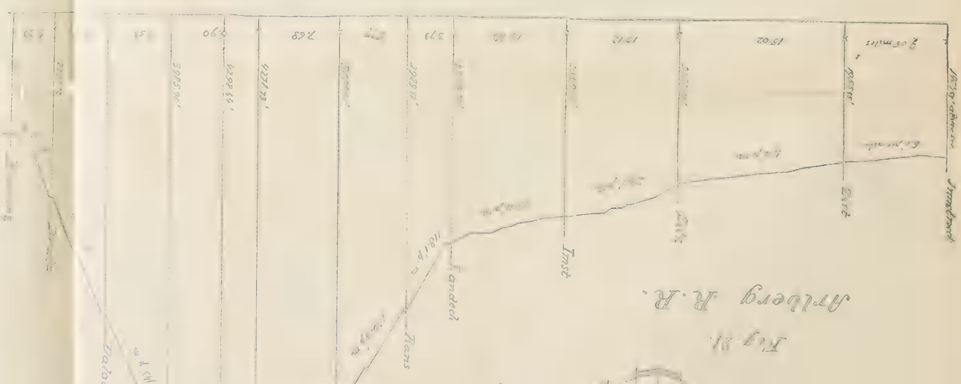
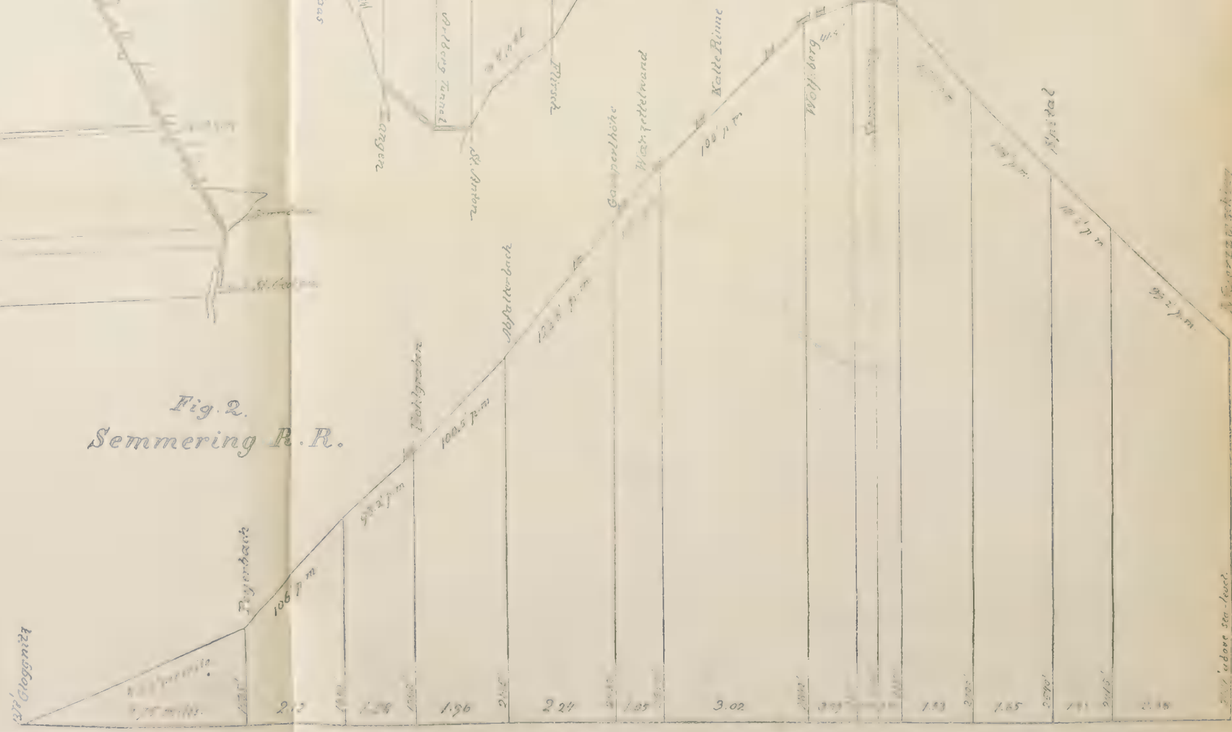


Fig. 2.
Semmering R.R.



ision
nella

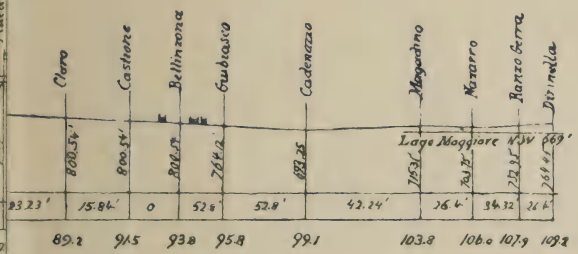
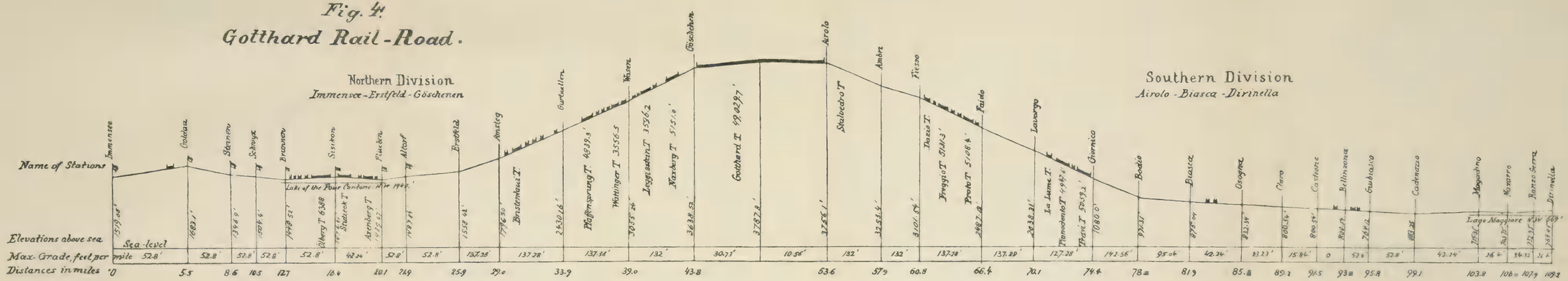

Claro
Castione
Bellinzona
Giubiasco
Cadenazzo
Magadino
Navarro
Ranzo Serra
Dirinella
Lago Maggiore
800.54'
800.54'
808.88
768.2
787.35
787.31
787.31
787.31

Fig. 4.
Gotthard Rail-Road.



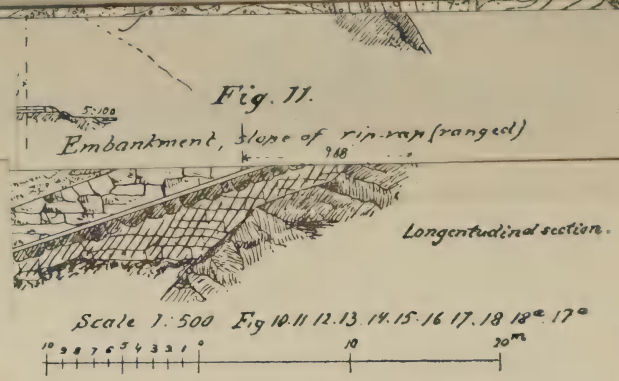


Fig. 11.
Embankment, slope of rip-rap (ranged)
Longentudinal section.
Scale 1:500 Fig 10.11 12.13 14.15.16 17.18 18a 17a
10 9 8 7 6 5 4 3 2 1 0
10
20m

Fig. 5.
Development at Wasen, Gotthard R. R. Scale, 1:25,000.

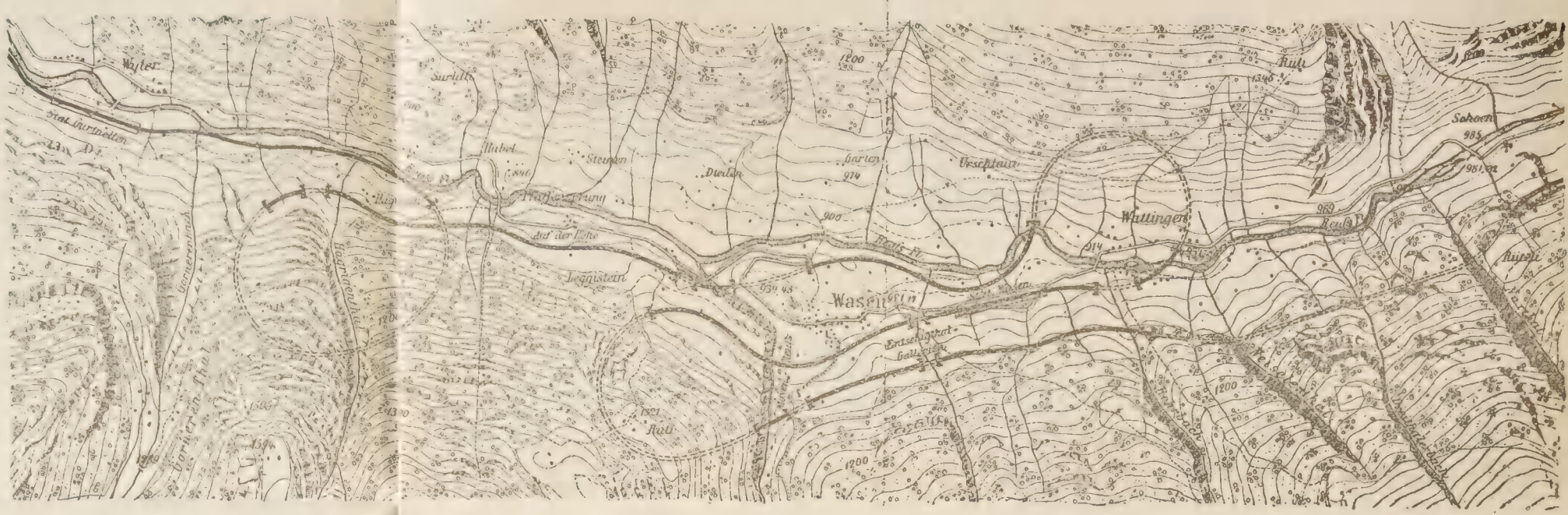
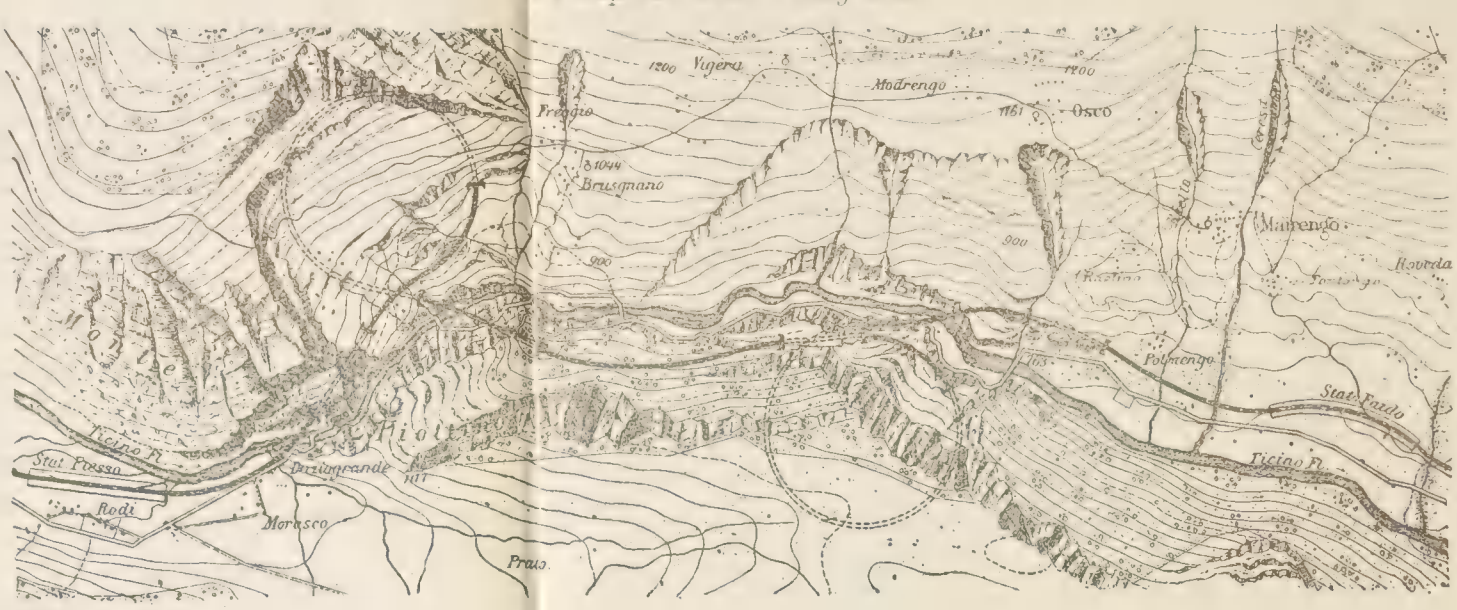
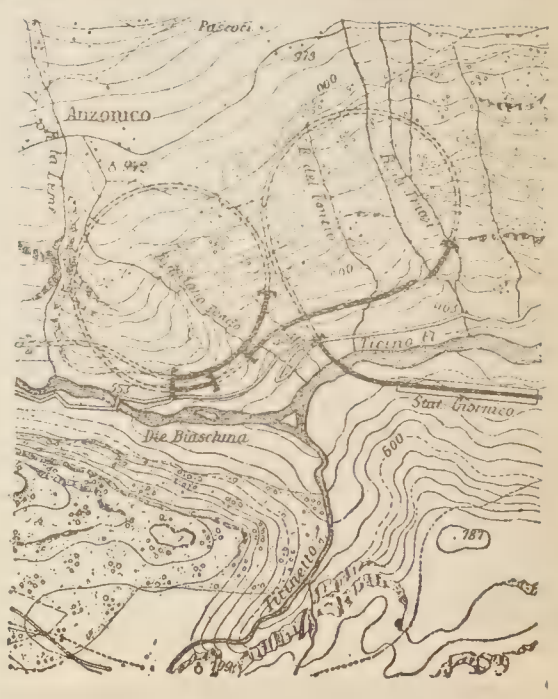


Fig. 6.
Development below Daziogrande.



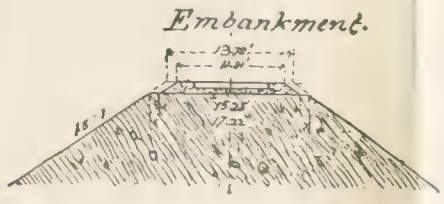
1:25.000.

Fig. 7.
Development in the Biaschina. Scale, 1:25,000.



Gotthard R.R.

Fig. 7
Embankment.



Cut in Rock
Fig. 9

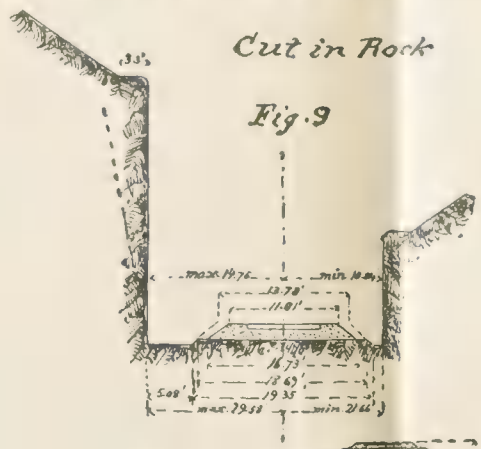
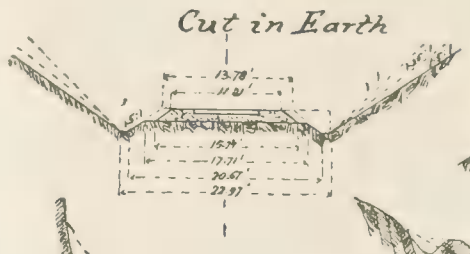


Fig. 8.
Cut in Earth



Edge of road-bed, made of rocks.

Fig. 8a

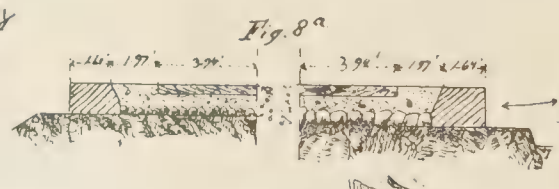


Fig. 8b

Fig. 12
Vertical Wall instead of embankment

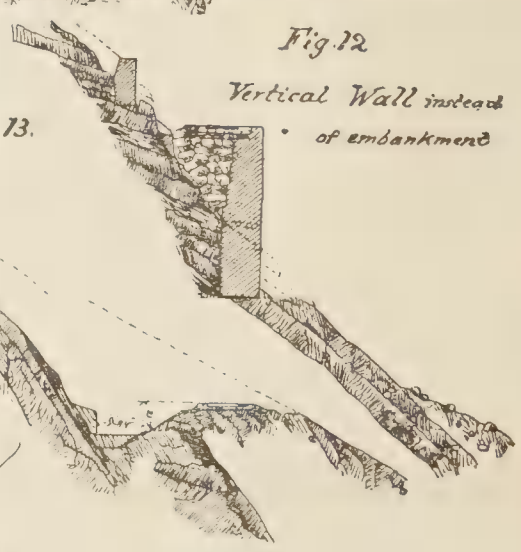


Fig. 10

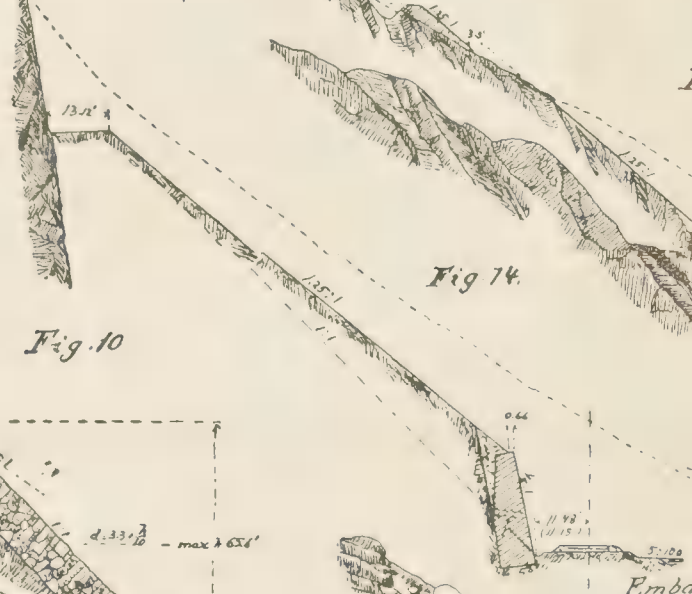


Fig. 13.

Fig 14.

Fig. 15

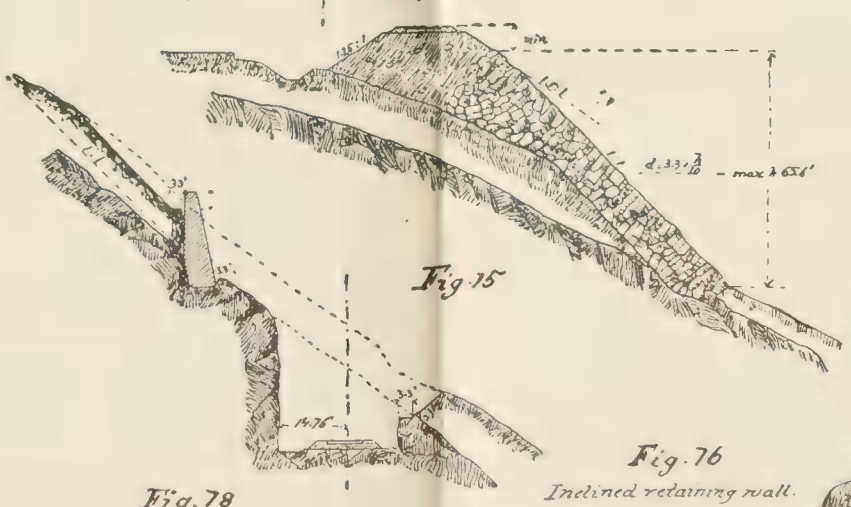


Fig. 11.
Embankment, slope of rip-rap (ranged)

Fig. 78
Vertical retaining wall with stone packing

Fig. 16
Inclined retaining wall.

Fig. 17a
Slope-protection
grade of river 80 p. m.

Fig 17
Slope-protection, grade of river 165 p.m.

Fig 20a Arched Culvert, on a steep slopes

Cross-Section *View from below* *Longitudinal section*

Fig. 78a. Retaining wall with buttresses and arches

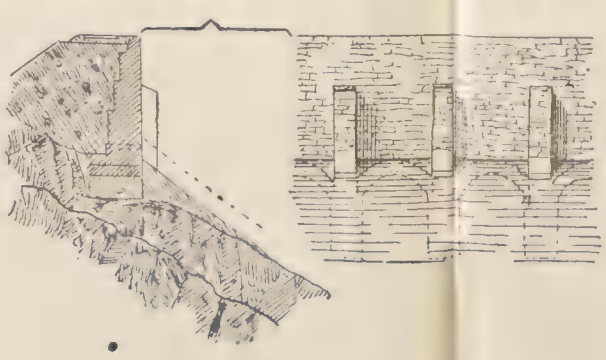
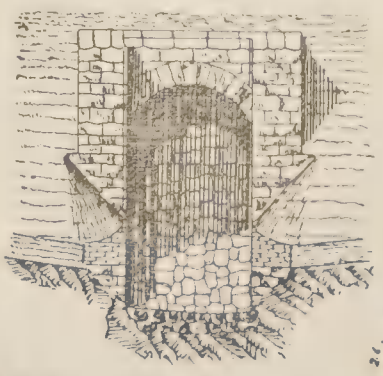


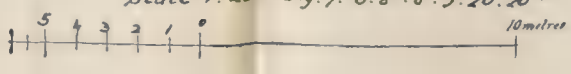
Fig 20
Arched Culvert with foot-path.



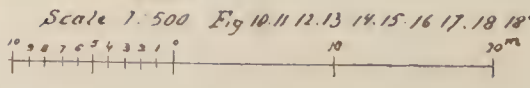
View from below

Longentudinal section.

Scale 1:250. Fig. 7. 8a. 8b. 9. 20. 20a



Scale 1:500 Fig 10. 11. 12. 13. 14. 15. 16. 17. 18. 18a. 17a



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXVI.

(VOLUME II —NOVEMBER, 1885.)

DYNAMITE CATASTROPHES.

BY FRED. H. JENSSEN, M. Tech. Soc.

[Reply to Mr. L. J. LeConte's Paper: Are not Dynamite Catastrophes intimately connected with Electric Phenomena?]

Read Nov. 6, 1885.

In a paper read before this Society in August, 1885, by Mr. L. J. LeConte on the above named subject, reference was made to a paper read by me at our regular meeting in December, 1884, which, he considers, enables him to establish a theory partly based upon the conclusions and facts therein stated.

In his introductory Mr. LeConte says that writers on Dynamite maintain, that acid nitro-glycerine decomposes and becomes very sensitive when the temperature reaches 100° F., * * * and when nitro-glycerine or dynamite is manufactured, the direct heat of the sun's rays should be prevented, otherwise decomposition of these materials will ensue, whereas in his experience of seven years with temperatures varying from 115° to 128° F., in the direct heat of a summer sun, he has not met with a single accident.

As these remarks (qualified) were made by me, it is proper that I should explain them.

It is an established fact, universally admitted that acid nitro-glycerine decomposes readily at 100° F. The greater the quan-

tity and the stronger the acid, the quicker the decomposition will ensue.

Pure neutralized nitro-glycerine or dynamite will stand 170° F. for some time before it decomposes. Long experience has demonstrated the fact that dynamite cartridges in boxes can sustain a temperature of 128° F. for years. But where the dynamite without covering has been exposed for a considerable length of time (varying with the quality) to the sun's rays, on touching it with blue litmus strips, the paper turns red.

Mr. Le Conte states that 90 per cent. of all the explosions on this coast since 1879, occurred during violent dessicating north wind storms, and that electricity has been the exciting cause in all these cases. However, admitting the existence of a dry north wind at the time of the several explosions, it is a fact that the survivors of two of them give reasons for their occurrence, which are at variance with Mr. Le Conte's theory.

At Stege, explosion on March 25th, 1882, the disaster occurred during the manufacture of black powder, called Vulcan B B. This powder is composed of nitrate of soda, sulphur and charcoal, which are mixed in a perfectly wet state. During this mixing process the superintendent called the foreman and told him that the mixture was not wet enough, and that he should put some more water in the basin—as it had been demonstrated by experiment that when the mixture fell below a specified percentage of moisture it would ignite by the friction of the machinery. A few moments after the departure of the superintendent, and before the water had been added, the explosion took place.

It may be possible, although not probable, that the north wind had dried the mixture to that dangerous extent, but then it was clearly the duty of the foreman to have his mixture of a proper consistency, thus avoiding all danger during the process of manufacturing.

The second explosion which took place at the Giant Powder Works, January 21st, 1883, was, as I had previously stated, caused by sparks blown from a wheelbarrow full of hot ashes into a box of dynamite. To the description already given in my

former paper, it need only be added that the furnace was situated on the north side of a row of buildings in which the dynamite was to be stored. Therefore this accident can hardly be attributed to a dessicating wind or electricity.

The second conclusion Mr. Le Conte arrives at is, "that the first explosion in the works is a phenomenon of dust explosion, and the giant powder explosion, apparently instantaneous, is nevertheless a secondary result." Apropos of the explosions, which Mr. Le Conte mentions, namely, at the Hercules Works, January 11th, 1882, in the nitro-glycerine department; also, those of January 19th and June 7th, 1883, at the Safety Nitro Works, it should be stated that in the nitro-glycerine department of the dynamite works there is no dust of any inflammable nature, nevertheless a number of explosions have taken place in that department, especially during the first years of the manufacture of dynamite, but now are of rare occurrence. The mixing department in a dynamite factory is the only place where dust exists. In all the dynamite explosions named, with the single exception of that at the Hercules Powder Works, September 29th, 1883, no explosion started in the mixing house, and not one of them can be traced to a dust explosion. On pp. 205–206, Vol. I, Transactions of this Society, I state that the dust arising from the mixing-pan is a source of great danger, and the steam or hot-water pipes should be cleaned regularly so as not to give the small particles of nitro-glycerine contained in the dust an opportunity to decompose, and that special care must be taken in making Nobel's explosive gelatine. This latter warning referred to the probable future introduction in this market of Nobel's explosive gelatine, which so far has been manufactured here only on a very small scale, and no explosions have occurred. Mr. Le Conte interprets these remarks in connection with his theory in the following way:

"Mr. Jenssen states that, in the process of manufacture, the rooms in the building are more or less full of dust from the dry absorbent used in making dynamite, and that this dust on examination is found to be saturated with acid nitro-glycerine."

This is a misconstruction of my remarks; as it can be here stated that there is very little dust arising from a mixing-pan,

although in time it will form a thin coating on the pipes and walls of the building, but the amount of dust suspended in the air at any one time can scarcely be estimated.

Moreover, there is no dust saturated with acid nitro-glycerine. Nitro-glycerine, in a well regulated factory, never should and never does enter the mixing-house. The dry absorbent, after being saturated with nitro-glycerine, forms a heavy moist substance.

It is, of course, easily understood that a stroke of lightning will explode dynamite. Explanation is unnecessary. But small sparks of electricity will not explode dynamite. This has been fully proven some sixteen years ago, by a committee of three well known experts, who were appointed by the Swiss government to report as to the physical qualities of dynamite. The conclusion reached by these gentlemen, as published in their report was:* "that thunder storms and lightning involve no special danger for the dynamite. As far as conclusions can be drawn by small experiments with large discharges of electricity by lightning, dynamite, unless well confined, will only burn if struck by lightning. But if well confined, and if the temperature produced by the lightning is high enough, an explosion may possibly take place. This is the reason I give for the explosion at Cheyenne, mentioned by Mr. LeConte, and possibly for that of the Hercules Works, September 29th, 1883, although I doubt the latter, as lightning very seldom strikes houses, etc., near this bay.

Mr. LeConte mentions as an authority, a man who had seen sparks fly during the manipulation of the ingredients, and who had quit work on that account. Sparks flying during the manipulation of dynamite ingredients certainly would induce everybody to quit the work, but I wish Mr. LeConte had asked where the sparks came from, where they went to, and how they looked. During eight years experience in Europe I have seen exceedingly heavy thunder storms passing across powder works, and although as a rule all men went to a place, where there was no dynamite, I was obliged several times to stay. I have been on this Coast during two years almost daily in the powder houses of one of

* Tranzl, Nitrilverbindungen, Wien, 1870.

the largest factories, and I never have seen any electrical phenomena either in the powder, in the ingredients, or in the different buildings.

If electricity and dust are the principal agents of an explosion, why does not an explosion happen during every north wind at all factories? We had one of the strongest north winds in December last, and an electric storm in January or February of this year, although I do not remember if the latter was at the same time a north wind, but there was no explosion in any powder-factory during that time.

Reviewing the paper of Mr. LeConte, it appears to me that the theory advanced is not warranted by facts, but on the contrary is disproven by them. It is true that a great deal yet remains to be done to perfect powder manufacture, and prevent explosions, and on this Coast it is greatly to be desired that liability to loss of life by explosions should by a proper arrangement of the works be brought to a minimum.

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XXVII.

VOLUME II.—DECEMBER, 1885.

REMARKS ON THE PRINCIPLE OF THE LOGARITHMIC SLIDE SCALE.

BY HUBERT VISCHER, M. Tech. Soc.

Read December 5th, 1885.

The employment of mechanical devices for performing operations of computation has attracted the attention of arithmeticians for a couple of centuries past, and is to no class of persons of more direct interest than to those engaged in technical callings. These endeavors have been pursued upon several distinct lines, and we may notice by way of classification:

1st. The endeavor to perform desired arithmetical operations by devices distinctly mechanical in their nature, and seeking by the skillful combination of mechanical elements to carry out the ordinary sequence followed in the computer's calculation, which they seek to replace. We may here mention the celebrated machine of Babbage, and as a more recent illustration the "Arithmometer" of Thomas, an instrument of only moderate cost, and one coming constantly into greater use.

2d. The use of geometrical figures representing the mathematical relations subsisting between mutually interdependent qualities, which, first suggested by the development of the Des

Cartian geometry, have in very recent times, developed into a new science—that of graphostatics—which not merely seeks to graphically present the deductions of analytical reasonings, but which, starting at the elements, builds up, step by step, methods of its own in which the arithmetical conceptions of magnitudes fall more and more into the back ground and are replaced by operations, mechanical at least in their application if not in conception, and it goes for granted what an agent of constantly increasing power the graphostatics have become in adept hands.

Besides these two methods, we have another, somewhat partaking in nature of both the preceding, yet embodying a distinct principle of its own—that of the Logarithmic Slide Scale.

It is with this last idea that I propose here to concern myself, and to devote what remains of the evening to a cursory survey of this field, as it is of wide application, certainly of interest as an important agent for the saving of time-robbing computation and worthy of more general employment than has been accorded to it in this country; although at least on the continent of Europe, the slide-rule has already become the engineer's daily pocket companion.

The slide-rule reduced to its primary elements owes its origin to a happy application of two most simple principles: the first, that magnitudes in general may be represented by the length of straight lines; the second, that these lines, when measured off upon one another may represent by the length of a resulting straight line either a summation or a difference of the magnitudes which the lines represent. The first principle underlies the logarithmic graduation of the scales; the second principle finds applications in the sliding motion which we impart to them. Slide-rules there are, as shall be shown, of various constructions and for many purposes, but they may all be reduced to a combination of these two elementary principles.

The use of the logarithmic graduation here, as in all other cases where logarithms are employed, is the outcome of the desire to reduce all arithmetical calculations by one step in the scale of mathematical operations; thus replacing multiplication and division by addition and substraction, or reducing involution and evolution to multiplication and division.

The method in which the logarithmic graduation is carried out is explained most easily by taking a special case, and we refer to the Scale *AB A′B′* on Fig. 1. The length of this Scale, measured between its two extreme outer limits, marked 1, 1, is assumed as a *unit of length*, and what the absolute length of this unit is, is perfectly immaterial. We may, for purposes of illustration, assume it to be just one foot long. As a preliminary step, let us first imagine this length divided off into say 1,000 equal parts. Before proceeding further, however, let us refer to the well known property of "periodical repetition" peculiar to Briggs' system, applying both to the logarithms and their numbers, whereby all numbers represented by the same numerals, grouped in the same order, are represented by the same logarithm independent of the characteristic or mantissa.

It is clear that, assisted by our table, we may with the aid of our scale of equal divisions, at once assign to any logarithm in the table a place on the scale, such that its distance from the zero, or left-hand end of the scale may correctly represent the value of the logarithm, plotted in our unit or standard of length. Doing this for all logarithms, commencing say, at the number 1, and progressing constantly by any suitable interval (say 1–100 of unity), let us mark each so determined point by a cross-line on the scale, and in order to preserve it for future use, mark opposite the cross-line the *number* corresponding to the logarithm which the cross-line fixes.

Having done this, we of course reach the right-hand end of our scale, when in our table we reach the number 10, and it is apparent that our scale represents graphically a table of logarithms for all whole numbers between 1 and 10, with suitable subdivisions corresponding in all particulars to the printed table from which it was constructed. And it is equally clear that if we agree to consider the scale as only representing the fractional part of the logarithm without reference to the "characteristic," we may at once extend its range so as to embrace the whole field of positive numbers without any reservation. The "characteristic" of the logarithm, however, only determines the position of the decimal point in its number. Therefore this stipulation about dropping the characteristic implies, conversely,

that our scale shall only give us the numerals which express a number without reference to the decimal point, so that, if we read 2, 3, 5 on the scale, we may read this as 235, or as 235 with any number of oughts affixed or prefixed to it, as 0, 00235 or 2350, for example. In Slide-rule calculations there must always be some foreign means employed for correctly assigning the position of the decimal point, to which I shall refer again later on.

I have now practically shown the construction of a logarithmic scale—only one, however, of an infinite variety of possible logarithmic scales. Any series or group of numbers may be made the basis of a similar scale. Thus, by means of their logarithms, we may construct logarithmic scales for the natural series or tangents of angles (see Scales E and F, Fig. 2), or for any other function of angles; or, as the choice of the length of our unit was left perfectly open, we may plot scales to any enlarged or reduced scale, which latter observation is important, as it forms the basis of all operations embodying involution and evolution in the slide-scale calculations (as will at once appear by remembering that these operations, logarithmically speaking, imply multiplication and division).

Returning, however, to our constructed scale, Fig. 1, let us conceive it severed longitudinally along its central line by a cut, *a b*, so as to fall into two identical scales, AA′ and BB′; and furthermore, let us regard these scales as free to slide laterally to the right or left along their common line of contact, *a b*. With this motion we at once obtain the means of effecting *any desired multiplication or division*, as is clear, if we consider that divisions upon our scale are magnitudes logarithmically plotted, and that therefore an addition or substraction, as far as they are concerned, executes a multiplication or division as regards their numbers (which are, by-the-by, the only records on the scale). With this capacity for motion, we have attained the simplest form of the slide-rule. A single setting of the slide performs a multiplication or division; if desired, a combination of both, *i. e.*, a proportion, and in many cases not simply for a single set of numbers, but for a whole series of sets of numbers at one and the same operation. The details of manipulation I shall not enter into here, having only the broad princi-

ples of the slide-rule in view. If desired these can all be found described at length in the printed directions furnished with the scales. Be it remarked, however, that although essentially the whole operation has been a logarithmic one, we lose sight entirely of logarithms having been used at all, which is always the case in operations with the slide-rule. In fact, the peculiar merits of the slide-rule can hardly be better expressed than by pointing out this unconscious gaining of all the advantages of using logarithms, while saved the labor of taking them from tables; that while the whole conception of the slide-rule is logarithmic in its nature—save as a means of understanding its construction and studying out particular modes of application to meet special cases—this is lost sight of entirely in use.

The Slide-rule, as constructed by the firm of Dennet & Pape, (in Altona), is shown in figures 1 and 2, the latter being an isometrical view of the scale to better show its working parts. These are as follows: A thin slab of boxwood called the "slide," upon the edges of which two scales, *B* and *C*, are engraved. The slide being fitted with tongue-and-groove edges at its sides, is free to move between two other boxwood surfaces also bearing scales, *A* and *D*, and which latter are parts of the same piece of wood, being connected with each other underneath the slide, and both, together with the connecting boxwood member, forming the "rule," into which the slide is recessed laterally while left perfect freedom of motion lengthwise in both directions. Scales *A* and *B* are, as has been shown, exact duplicates of one another, as are also scales *C* and *D*, thus forming two pairs of scales. The latter pair, in principle of graduation correspond to the former pair entirely, but are graduated to one-half the scale (or length of unit) of *A* and *B*. This reduction in scale would make each of the upper scales one-half the length of the lower pair, were it not that we utilize the remaining half by engraving thereon another duplicate set of the smaller scales, placed alongside of the former; thus making the total length of the upper *double pair* exactly that of the single lower pair. Each half of either "double scale" is not to be regarded as separate from its neighbor, but as joined to it, so as to form one continuous scale—with the object in view of allowing the double scales to represent all

numbers for an interval of two whole powers of 1o—while the lower scales represent all numbers for half that interval; so that if the lower scale embraces, for instance, the period from 1 to 10, then the upper similarly represent that from 1 to 10 on their first (or left hand) halves, while their second (right hand halves) simultaneously represent the numbers from 10 to 100. The pair of scales on the slide (though movable as a pair) stand permanently with their extreme ends directly over and under one another; so also stand permanently fixed opposite one another the ends of scales *A* and *D*.

Now while the double scales *C* and *D*, on account of their lateral motion along their common line of contact, answer the same purposes exactly that the lower pair do (that is, perform multiplication and division also), a little reflection and study of the figure will show how, regarding *A* and *D* or *B* and *C* as pairs, the following must always hold good, on account of the peculiarities of the mode of graduation: any number on the upper scale stands directly over its root on the *corresponding* lower scale; and conversely, any number on a lower scale may be raised to the second power by taking the corresponding number exactly above it in its companion scale. Thus a simple transfer made in a suitable manner from either scale to the other, at right angles to the axis of the rule, effects an involution or a radication to the second degree; and either of these operations may be combined at will, with multiplication or division by a movement of the slide.* Involution and evolution to higher powers may also be executed by the Slide-rule, though we merely note the fact here.

The "Slide," however, can be completely run out of the rule and re-inserted, when so desired, reverse side up. The reverse side of the slide bears two scales, *E* and *F*, being respectively logarithmic scales of natural sines† and natural tangents,‡ and also a third scale, *G*, bearing equal divisions (1–1000ths of the scale length), answering the purpose of a table of ordinary

* To accurately effect this transfer a small brass part, called the "runner," is provided. See Fig. 2, *A*. This slides freely along the rule in grooves on its outer sides, and carries two indices, *a*, *a*, which accurately transfer points from one scale to another.

† Of angles from 0° 35′ to 90°.

‡ Of angles from 5° 43′ to 45°

printed logarithms, in which the numerical value of any logarithm may be read off.*

With the slide in the reversed position the Slide-rule presents the appearance shown in Fig. 2; and when used in combination with each other, scales *A*, *D*, *E* and *F*, enable us to perform any calculation into which enter the trigonometrical functions of angles, combined in any way by multiplication, division, involution or evolution with quantities expressed in simple numbers.

Our Slide-rule, now fully equipped, is an instrument only a few inches long,† suitable for being carried in any person's breast pocket, and of but trifling cost; and to enumerate its various uses, it at once serves us as a table of numbers and their squares and cubes, their square and cube roots, is a table of common logarithms, of natural sines, cosines, tangents and cotangents. An agent besides, capable of mechanically combining any of the above functions in any desired arithmetical combination, constantly showing up to better and better advantage the more complex the nature of the form of combination; a convenient pocket rule and straight edge, for it is both of these; and contains printed upon its reverse side a valuable list of useful pocket data of many, frequently used, practical co-efficients. Yet while being all these combined, alas, absolute perfection is unattainable! It must be admitted it has its shortcomings also. Owing to the mechanical difficulty of graduation, and the uncertainty of reading results closer than to the third (at times the fourth), numeral place, it remains, notwithstanding all its theoretical perfection, practically an instrument only applicable where no greater accuracy than that of the third or fourth figure is required.

Its use must always be a judicious one. The banker, computing interest or exchange upon extended rows of figures, will find the slide-rule fall short of his requirements. And its accuracy is inadequate in many calculations of the engineer, and many have undoubtedly cast the Slide-rule scornfully aside, only half

*Scale *G* is really the scale of imaginary equal divisions first referred to as a preliminary step towards graduating our original scale, *A*, *A'*.

†Generally 26 centimeters, or 10 inches.

examined, on account of the only approximate accuracy of its determinations.*

These shortcomings freely admitted, it still remains an invaluable assistant, and serves to good purpose wherever a limited degree of accuracy is required—and this after all holds good in the vast majority of cases in engineering practice. In construction, wherever we have to deal with practical co-efficients, (generally themselves but approximations at best) where, moreover, wide factors of safety are generally introduced, and where, after all practical considerations usually dictate conformance to some nearest marketable standard size of a part or member—here, always, the Slide-rule gives us results quite as reliable as the most elaborate calculation carried out to the fifth or sixth decimal place. In estimates of earthwork, where our surveys are at best but close approximations to the true condition of the ground; for proportionately distributing minor errors; for interpolating intermediate grades; for at once transforming quantities expressed in one standard unit to equivalents in another standard—for all these purposes, on account of its great rapidity and freedom from liability to "mistakes," the Slide-rule cannot be too highly estimated.

It may not be equal to figuring traverses closely to the one hundredth and the one thousandth parts of feet (and how very seldom do our measurements really warrant such subsequent super-refinement in calculation); yet even here it may do good service as a check against "mistakes," and there are hundreds of cases where its use in the field may obviate the many half and quarter hours consumed—with a party standing idle all the time —while one man alone is busy figuring out a "closing course" for a trial line to obviate a meander or other frequently recurring field problem of location. We have, besides these cases, another frequently recurring set, namely, where the relations

*Notwithstanding the above remarks, those who really make a study of the Slide-rule will be astonished at the accuracy it can be made to yield in the hands of a mathematical adept. The Slide-rule namely often contains in itself the means of overcoming its own deficiencies. Thus used, the ordinary limit of the third or fourth numeral place falls away, and that of the sixth or seventh place appears as its limit in its stead. For instance, any rapidly converging series applied to the rule extends its range at once immensely. This study of the ultimate possibilities of the Slide-rule and its special applications is a highly interesting one to any one with leisure to devote to it.

expressed in an equation are so complex as to make solution only practical by continued approximation, or where we have to assume co-efficients, themselves functions of the element to be determined; where, *assuming* some probable value of the required quantity, we gradually, by successive trials, adjust all elements to conformity, as this so frequently occurs in hydraulic work. Here we can always use the Slide-rule advantageously for the first stages of the calculation, and when tolerably certain of being "near the mark," can then resort to ordinary modes of calculation in the last and final stage.

From what has been said of the general accuracy of the slide-rule, one important corrollary should be drawn; to use it successfully, that is, *rapidly*, we should never waste time in straining at the last hair either in setting the scale or in reading a result; this will reap no adequate return for the extra labor spent.*

We will now close our observations on the ordinary Slide-rule, remarking that our Figures, 1 and 2, are only illustrative representations of the rule, and only show the main subdivisions. An idea of the fineness of the graduation actually used may be derived from Figures 3 and 4, which show the Slide-rule of Le Noir. This is the rule, unfortunately, which has been most widely introduced into this country, and although apparently but slightly differing from the scale of Dennert and Pape, falls much short of the latter in practical efficiency. The most essential difference consists in its having three (3) of the "double scales," and only one single scale, instead of two of each kind—and we miss the runner. Slight variations in the arrangements of the slide make great differences in their degree of serviceability.

The Slide-rules already described are generally applicable to all calculations, and there is no calculation which cannot be executed by carrying out with the rule, step by step, each successive intermediate operation necessary to attain the result. Thi , however, often necessitates several settings of the scale to obtain a single result. To avoid this extended manipulation, however, special slide-rules may be constructed, capable of solv-

*In using the scale this is essential, as also that the slide should move with perfect freedom, though not so freely as to slip by an inadvertent touch. To effect this, keep the grooves clean, and, if necessary, lubricate with a drop of fine oil.

ing almost any such case by one single, or at least by a greatly reduced number of settings of the rule.

Speaking generally, any function of two variables combined with constants, may be solved by one movement of a specially constructed rule, the peculiarity of the special construction being, that the constants be embodied in a suitable manner with the variables directly. With each additional independent variable above two, one more movement is required, generally necessitating the introduction, however, of an additional scale.

Figure 5 gives an illustration of this kind, showing a scale very widely used in Germany in topographical work. With Stadia measurements for direct readings of a vertical rod, we have the formulæ:

$$D = K \cos^2 \infty \; a$$
$$H = \tfrac{1}{2} K \sin 2 \infty \, a.$$

Where ∞ is the angle of elevation above the horizontal, K, a constant dependent upon the construction of the telescope, and generally so adjusted as to be exactly 100; a, the reading on the vertical rod between the stadia hairs; D, the corrected distance of the observed point from the instrument; and H, its elevation above the horizontal plane through the horizontal axis of the telescope.

In this slide scale we have the slide bearing two scales, the upper scale graduated to $\frac{1}{2} \sin 2 \infty$, the lower one for $\cos^2 \infty$. The rule carries two identically graduated scales of common numbers representing the rod readings, a. Setting the index of the lower scale to coincidence with the rod reading, we read directly on the lower scale opposite the observed angle ∞, the corrected, *i. e.*, horizontal distance D, and on the upper scale the difference in elevation, H.

This scale is very serviceable, but as usually constrnected is too long to be convenient for anything but office use. Fig. 6 shows another scale for the same purpose, executed in metal, fitted for being used in the field, a vernier being employed, and the finer metallic graduation being relied on to make up in accuracy what otherwise would be sacrificed by the reduced length of the scale.*

*This scale, either in the form of Fig. 6 or Fig. 7, is also very convenient in running grade lines, enabling the transit-man always to select his grade points on the ground, and keep track of his elevations without the aid of the level, and judiciously used will often save much "backing up" in field location.

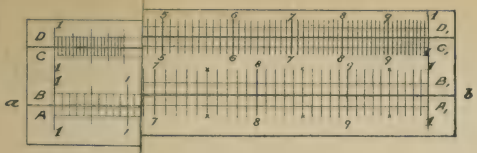
Another direction also presents itself for development of the slide rule by artificially extending the length of unit (without correspondingly increasing the size of the instrument). In his catalogue of instruments, Stanley, of London, describes an instrument by Professor Fuller. Here by developing the scales upon a spiral line upon a cylinder, a length of unit equivalent to 83 feet is attained; of course, thereby very materially increasing the accuracy of the slide rule, although probably not nearly in the ratio of the increased length (which is about one-hundred fold that of the ordinary slide rule). This instrument is advertised at £3, and a smaller size 200 inches long for £1.

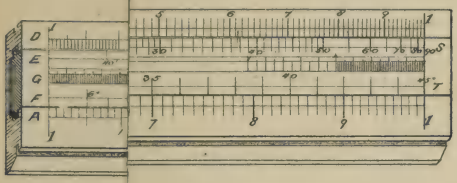
Figure 7 shows the very interesting calculator of Professor Herman, of Aix-la-Chapelle, also a slide-rule in principle. In this instrument, additional length of unit is attained by development of the scale upon a circle; besides, on account of the great number of scales combined together, a considerable extension of the range of direct application is attained over the ordinary slide-rule. We have ten scales, directly giving simple numbers, squares, cubes, areas and peripheries for given diameters, logarithms, sines and tangents, with the last two a separate scale being provided for each set of angles, the characteristics of whose logarithms are represented by the same figure. The scales are all mounted upon a zinc disc (which is capable of being freely turned on its axis) and two needles—one fixed, the other movable. Expressions as complicated as—

$$\sqrt{a}\,\frac{\sqrt[3]{b}}{c} \quad \text{or} \quad \frac{a^2\,\sqrt[3]{b}}{\sqrt[3]{c^2}} \quad \text{or} \quad \sqrt{\frac{a^3 b^3}{c^3}}$$

selected at random out of a list of about fifty pattern forms, may be solved at one single setting and turn of the instrument.

The principle of the slide-scale was first applied by Gunter, shortly after the discovery of logarithms. It made little progress until the middle of this century, but since that time has found wide application. As has been indicated, the field is an unexhausted one, the principle capable of great development. Other mechanical constructions will undoubtedly arise which surely will extend both range and accuracy and special applications to special cases lie within the reach of any one caring to apply them.





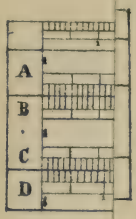
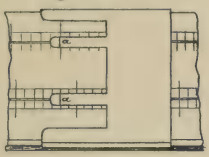
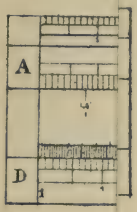


Fig. 2 A.





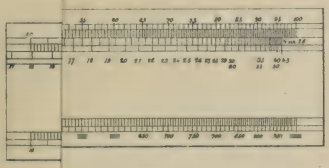


Fig. 6 A.

Fig. 1.

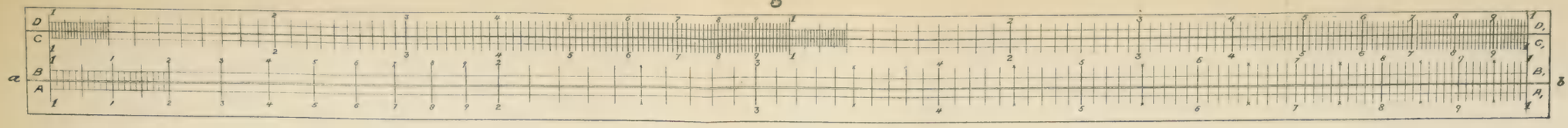


Fig. 2.

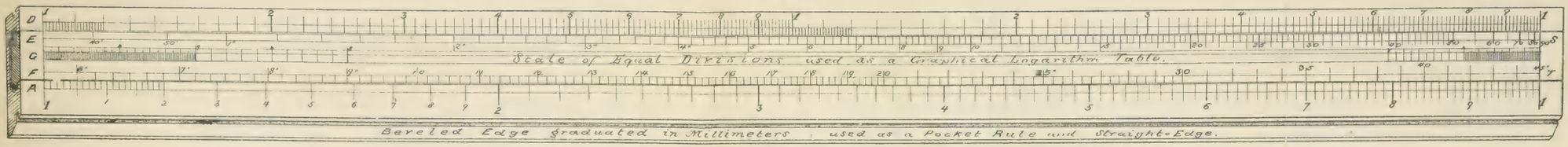


Fig. 3.

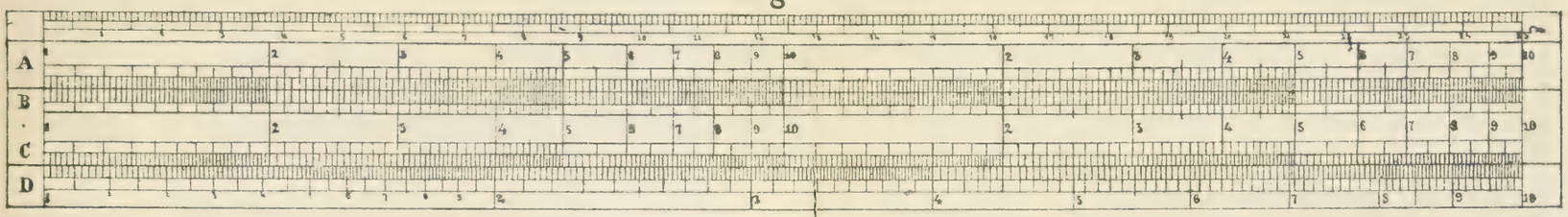


Fig. 2 A.

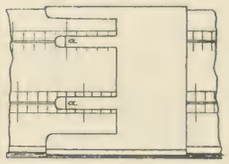


Fig. 4.

Fig. 5.

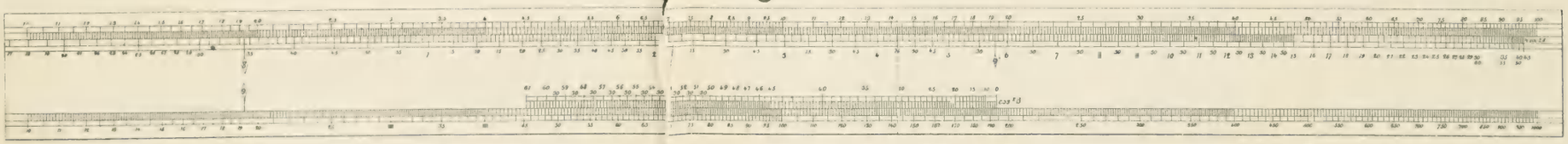


Fig. 6.

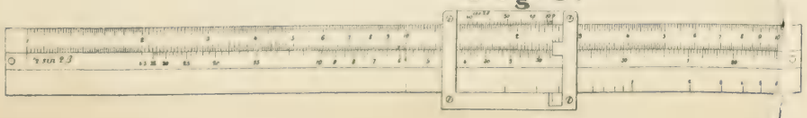


Fig. 5 A.

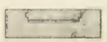
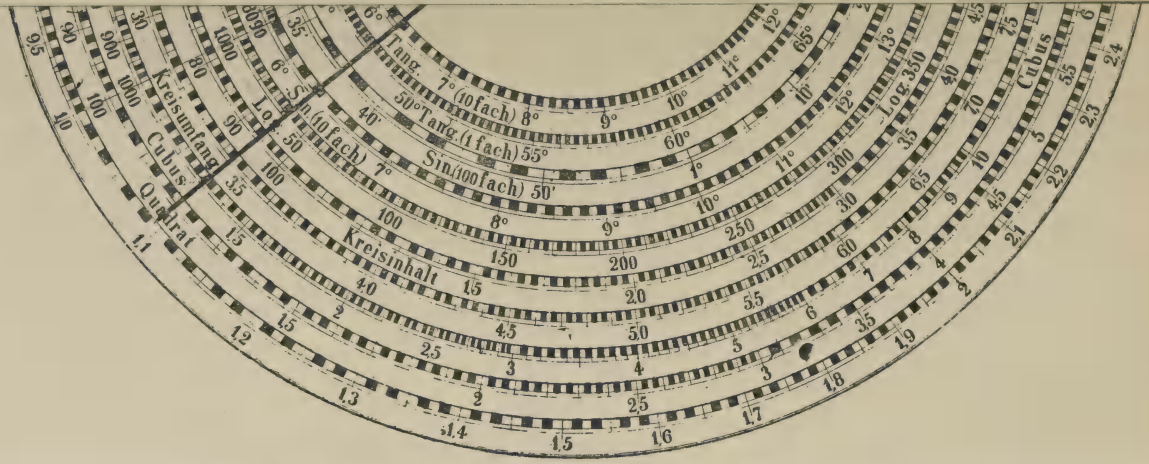


Fig. 6 A.


Tang. 7° (10fach) 8°
50° Tang. (1fach) 55°
Sin. (100fach) 50'
Sin. (10fach) 7°
Log. 50
Kreisinhalt
Kreisumfang
Cubus
Quadrat
Log. 350
Cubus

Tang. 7° (40fach) 8°
50° Tang. (1fach) 55°
Sin (100fach) 50'
Sin (10fach) 7°
Log. 350
Kreisumfang
Cubus
Quadrat
Kreisinhalt
Tang. (10fach) 25°
Sin (10fach)
Log. 650
Kreisinhalt
Cubus
Quadrat
Tang. (1fach)
Sin (100fach) 30'
Cubus
Quadrat
Kreisumfang
Kreisinhalt

Fig. 7.

SUPPLEMENTARY REMARK.

One of the chief difficulties to beginners in using the slide-rule lies in assigning to a result its correct local value; that is, to fix the position of the decimal point. Many do this by rule of thumb entirely, placing the decimal point by guess work, whereby mistakes are liable always to creep in. The most satisfactory method is to preserve in one's head the logarithmic characteristic separate, and mentally to execute the operation implied by the calculation, regarded as a logarithmic problem. The result of this simple calculation always fixes the local value of the result correctly. For example, say 230 is to be multiplied by 0.0003, and the result divided by 2.7. Then we have 230 [characteristic + 2], 0.0003 [characteristic — 4], 2.7 [characteristic 0]; then $+2+(-4)-0=+2-4=-2$. The slide-rule gives the figures of the answer to four places 2555 (the last place a little uncertain), and from the foregoing we know the correct value of $230 \div 2.7 \times 0.0003$ to be 0.02555. An additional unit must, however, always be added or substracted every time we have to resort to a substitution of one index for another in attaining a result, or when we read a result by passing through an index (which corresponds entirely to carrying a unit or borrowing one where ordinary logarithms are used). A little practice, however, teaches us how this is to be applied. To illustrate: $56 \times 7 = 392$. If not modified, our rule would give us $1 + 0 = 1$, or 39.2 as an answer. To obtain a reading at all, a substitution of the indices was required for which a unit must be added, when we have $1 + 0 + 1 = 2$, giving the correct result 392. Or say we inquire how often 7 goes into 56. For the position of the decimal point, we would have $1 - 0 = 1$, or the answer, 80 times. We had, however, to use the right hand index to obtain a reading, where ordinarily the left hand index would have given us the answer. This substitution implies our substracting an additional unit, and we have $1 - 0 - 1 - 0$, or $56 \div 7 = 8$, the correct answer.

This calculation is never too difficult to be kept in one's head save where the operation is a lengthy one, when it is well to keep the characteristic, as was done above in the process of illustration, on a separate scrap of paper, or to provide the slide-rule with some separate recording device for keeping the characteristic. A simple device for this purpose is that of Mr. Deering, of the S. P. R. R. A small annular disc, free to revolve around a center, upon which a radial scratch used as an index is marked, is provided with several radial divisions to either side of a central initial mark or zero. The disc is turned a suitable number of places to the right or left to record the characteristic when the slide is set to the number and its position shifted appropriately at each stage of the operation; the index on the fixed center finally indicating the correct position of the decimal point. This little device is mounted on the "runner" of the slide-rule, and can be easily turned with the finger while one manipulates the runner.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXVIII.

VOLUME II.—DECEMBER, 1885.

THE GOLDSCHMID ANEROID.

BY GEO. J. SPECHT, M. Tech. Soc.

Read December 5, 1885.

It need hardly be stated that all aneroid barometers make use of the elasticity of a hermetically sealed box, or other closed compartment in which a partial vacuum has been established, to measure changes in atmospheric pressure. The movements of the box, always small, are magnified by means of a somewhat complex system of delicate levers in the ordinary aneroid forms, of which that of Naudet's make may be taken as a type. The extreme delicacy of the intermediate transmission has always proved the objectionable feature and the main source of inaccuracy, and it was with the object of totally suppressing this transmission that Goldschmid successively designed the series of instruments which bear his name.

The movements of the vacuum box were observed either by a micrometer screw or, as in the Goldschmid-Weilenmann's aneroid, several boxes are mounted, one upon another, the upper one of the series carrying an index, whose motion is observed by a minute telescope provided with cross-hairs, and mounted upon a micrometer screw.

The original instrument with a single box proved deficient in delicacy, and the compound-box aneroid disappointed the expectations of its designers in not possessing the requisite qualities of standing ordinary rough handling in shipment or field use. While giving admirable results when left stationary or carefully carried upon an observer's person, curiously enough this compound-box aneroid (No. 3), showed that sudden jars produced very considerable changes in the instrument—not abrupt changes only, but changes such that often weeks and months were required before the boxes again assumed a state of equilibrium. This deficiency was all the more surprising on account of the construction having been so simple, and all intermediate transmission having been eliminated, that special freedom from liability to disarrangement had been confidently anticipated.

Since Goldschmid's death his successor, Hottinger, of Zurich, has continued his investigations, and after many modifications and changes, has produced the type of instruments shown in Figs. 1, 2 and 3, known as the Goldschmid Aneroid No. 1. The vacuum, *b b* (Figs. 1 and 2), is kept in tension by the steel spring, *f f;* this transfers the movement of the box-center to the lever, *h h*, turning on the fulcrum *a*. To the top of this lever, *h h*, is attached a hair-spring, *e e*. The movements of the box are measured by means of a micrometer screw, *m*, whose contact with the hair-spring, *e e*, must be ascertained with greater accuracy than is possible by the mere sense of touch, and is accordingly indicated by the coincidence of two black lines on the heads of the lever, *h h*, and the hair-spring, *e e*, observed by means of a magnifying glass, *L*. The scale, *S S* (Fig. 3), gives the full revolution of the micrometer screw. The first instruments of this class were provided with a scale on which the readings increased with the altitude, the value of the scale-unit being arbitrary. The scale of the more recent instruments is divided to correspond with the mercurial barometer. Each revolution of the micrometer screw corresponds to 10 mm. of the mercury column, and the head of the micrometer screw is decimally graduated, admitting of accurate reading to the one-hundreth part of a millimeter.

The usual size of this instrument is $3\frac{1}{8}$ inches diameter and $2\frac{1}{2}$ inches high. Fig. 1 is a vertical section; Fig. 2, a top view, the cover being removed; Fig. 3, a side view; *g g* is the outer shell; *r r* the revolving and graduated head; *h′* the end of the main lever, and *e′* that of the hair-spring lever, each provided with an index-line; *S S* the scale by which the number of full revolutions of the micrometer screw, *M*, are measured.

New aneroids give elevations at the ordinary atmospheric pressure (25 to 30 inches), correctly within one half of one per cent., the difference of elevation not being more than 750 to 1000 feet. For the determination of greater differences of elevation old aneroids should be used, in which the box has attained its equilibrium. Indeed it may be said that the instruments improve with age.

The influence of temperature upon 44 of these aneroids tested for a period of six months, at temperatures of 10° to 30° C. (50° to 86° Fahr.) was only 0.4 mm. per 1° C.

Each instrument is provided with a table of reduction, giving the value of its unit at different atmospheric pressures in millimeters, or inches of the mercurial barometer, and its value in inches or feet, and the corrections for temperature. Each is rated individually and tested daily for four months at the factory before being sent out. No. 2 differs slightly from No. 1 in construction; is considerably smaller, and less sensitive, and is better adapted for tourists than for engineers. Its probable error is nearly double that of No. 1.

In the aneroid No. 3 (Weilenmann's system), the small telescope already referred to is mounted upon a micrometer screw, which measures its movement. The cross-hairs of the telescope being brought into coincidence with the index on the upper of the combined series of boxes, the scale of the micrometer indicates directly the motion of the boxes in terms corresponding to the movements of the mercurial barometer.

The boxes are entirely independent of the micrometer screw, so that no changes in the instrument can occur by reason of wear on the point of the micrometer, or any other part. Its accuracy is so great that it can fully replace the mercury barometer at atmospheric pressure below 24 inches, and it is much more portable. Its size is 6 inches high by 3 inches diameter.

SELF-REGISTERING ANEROID OR BAROGRAPH.

The purpose of this instrument is to register automatically the readings of the aneroid, which consists of a number of boxes like the one just described, the movements being transferred by a lever to a paper on a drum revolved by clock work. Every hour a point is marked upon this paper, giving the reading of the aneroid. After 48 hours a paper 3 inches long is unwrapped, containing 48 equidistant points 1.½ mm. apart. The dimensions of this instrument are such that the maximum motion of the pointer is 2 inches, corresponding to the same movement of the mercurial barometer. Two-tenths of a millimeter can be read with certainty.

ACTUAL OBSERVATIONS MADE WITH A GOLDSCHMID ANEROID NO. 1.

The elevations given below were measured along the Gotthard stage road (Switzerland):

Station.	True Elevations. Meters.	Elevations Determined by Aneroid. Meters.	Differ'nce Between Both. Meters.	Station.	True Elevations. Meters.	Elevations Determined by Aneroid. Meters.	Differ'nce Between Both. Meters.
Office.	1178.2	.....	.....	8	1138.7	1139.0	—0.3
Cemetery.	1166.2	1166.2	.0	259	1136.2	1135.9	+0.3
1	1164.9	1165.6	—0.7	9	1130.3	1130.2	+0.1
2	1161.8	1163.0	—1.2	10	1130.3	1130.2	+0.1
3	1156.1	1158.0	—1.9	11	1126.2	1127.0	—0.8
4	1151.5	1151.6	—0.1	12	1122.2	1122.6	—0.4
5	1148 8	1148 5	+0.3	13	1120.9	1120.7	+0.2
6	1146.2	1145.4	+0.8	26	1120.9	.....	.....
7	1142.4	1141.6	+0.8	....	.....	.....	.....

Probable error, ascertained by the method of least squares: ±0.57.

89 similar observations gave a probable error (difference of elevations being 100 meters) 0.62 meters.

104 observations with greater differences of elevations, made in the neighborhood of Zurich, gave as probable error: 0.6 8meters.

In these observations the value of one aneroid-unit was ascertained by dividing the difference of the aneroid readings on both end-points by the true difference of the correct elevations. In the observations given below, the unit was determined by comparison with a mercury barometer :

Station.	Difference of Elevations Ascertained. By Actual Level. Meters.	By Aneroid. Meters.	Difference between Both. Meters.	Station.	Difference of Elevations Ascertained. By Actual Level. Meters.	By Aneroid. Meters.	Differ'nce Between Both. Meters.
1	...	..	.....	11	31 3	31.0	0 3
2	14.1	14 2	—0.1	12	35.3	35.5	—0.2
3	21.1	20.8	+0.3	13	30.4	30.2	+0.2
4	25 0	24.4	+0.6	14	41.3	41.2	+0.1
5	19.8	18.6	+1.2	15	50.5	50 6	—0.1
6	14.7	13.9	+0.8	16	60.5	60.9	—0.4
7	13.6	13.3	+0.3	17	78.5	77.8	+0.7
8	13.8	13.6	+0.2	18	102.3	101 5	+0.8
9	20 2	21.6	—1.4	19	118.1	116.6	+1.5
10	27.0	27.3	—0.3	..	.....	.....	.....

Probable error: 0.47 meter.

The probable error of the Naudet aneroid, ascertained by different observers, varies as follows: ±0 94, ±1.10, ±1.09, ±1.80. Comparing this with the above results, it is evident that the Goldschmid aneroid, No. 1, gives better results than the Naudet aneroid.

The following two tables give the differences between the true elevations and those ascertained by aneroid in six different trials along the Gotthard stage road, the differences of elevation being greater than in the measurements given above.

GOESCHENER—ANDERMATT.

Period of observation, 3 hours.

Station.	Elevation. Meters.	Differences Obtained with Aneroid. No. I. Meters		No. II. Meters.		No III. Meters.	
Office.	1128.5						
6	1137.1	—2.0	—3.5	—2.6	.0	—2.7	—0.7
6a	1185.5	—0.8	—5.0	—3.2	—2.2	—1.0	—4.1
6b	1206.8	—3 1	+0.6	1 3	+3.5	+2.6	—0.9
4	1235.3	—0.6	—1.0	0.4	+6.0	+2.1	+1.3
3	1339.2	+0.9	—0.3	+0.7	.0	—0.2	+2.1
2	1402.5	+1.9	—2.2	+2.7	+0.4	+5.1	+2.0
0	1445.4	.....	.....	.....	.....	.....	.....
Probable error,		±1.61		±1.82		±1.75	

Average, ±1.73.

AIROLO—ST. GOTTHARD.

Period of observation, 6 hours.

Office.	1177.6	I.			II.	
24	1357.1	+7.5	+0.3	—0.8	—3.2	+2.8
23	1429.9	+5.1	+1.6	—3.4	—5.8	+5.1
22	1462 2	+4.1	+6.1	—0.8	—1.9	—3.1
21	1536.9	—3.6	+3.0	—1.3	+2.4	—3.1
18	1696.6	—6.9	+0.2	+0.5	—3.9	—2.9
17	1766.2	—6.4	+5.6	+0.4	—3.5	—8.5
16	1829.0	+6.8	—1.1	—4.1	+1.2	—3.6
15	1920.1	+4.9	—6.1	—6.5	—5.3	—0.8
14	1968.4	—0.4	—3.5	—2.5	—5.8	+2.9
13	2026.8	+0.7	—6.7	+0.2	—0.1	+1.9
12	2043.4	+2.0	—6.8	—4.8	—8.2	0.

Hospice, 2100.0

Probable error, ±2.92 ±2.83

Average, ±2.87

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME II—NOVEMBER, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

November 6, 1885.

Vice-President Specht in the chair.

The following propositions for membership were made:

Olaf Windingstad, proposed by Hubert Vischer, G. J. Specht and Luther Wagoner.

Frank B. Morse, proposed by L. Wagoner, Hubert Vischer and L. M. Clement.

Wm. H. Shockley, proposed by Aug. J. Bowie, Jr., C. F. Hoffman and J. Ross Browne.

F. H. Jenssen read a paper on "Dynamite Catastrophes."

A discussion ensued on the subject of explosions in powder factories.

The chairman called attention to a circular which had been received from the Cleveland Society of Civil Engineers, asking the Technical Society to appoint delegates to a convention of Civil Engineers, to discuss the question of the employment of civil engineers on government works.

On motion of Mr. Bridges, it was resolved that the President appoint a commmittee of three or five to consider the question.

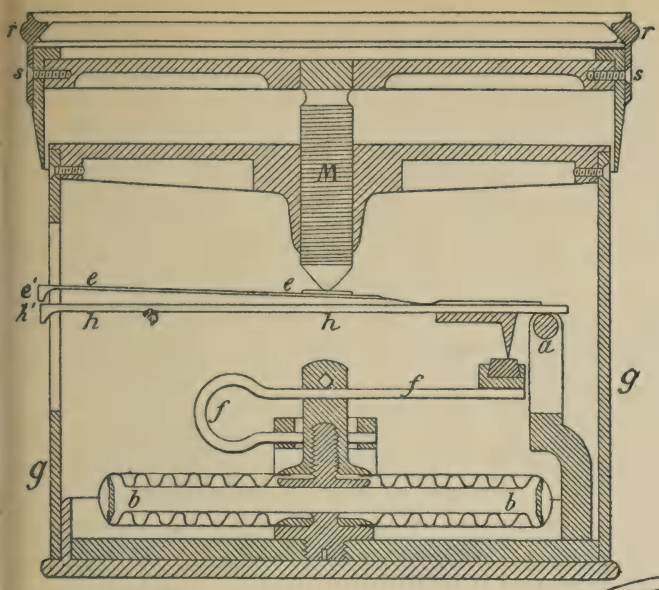


Fig. 1.

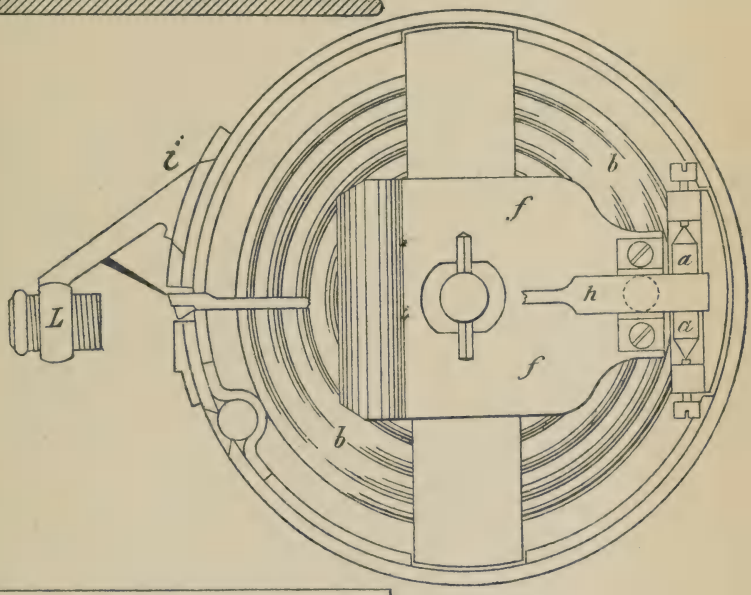


Fig. 2.

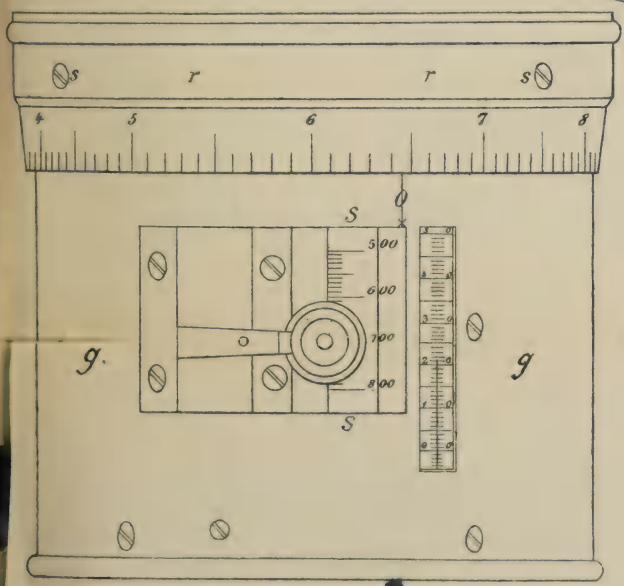


Fig. 3.

REGULAR MEETING.

December 5, 1885.

Vice-President Specht in the Chair.

Minutes of preceding meeting were read and approved.

The following were, on the ballots being counted, declared duly elected members: Frank B. Morse, Olaf Windingstad, Wm. H. Shockley, W. R. Sherwood and John P. F. Kuhlmann.

The Chairman announced that at this meeting a committee should be appointed to nominate a regular ticket for officers for 1886.

The following were nominated as members of said committee: E. J. Molera, E. L. Ransome, H. C. Behr, J. R. Mauran, Chas. Kluegel and L. Heynemann.

On ballot, the following were chosen: J. R. Mauran, E. J. Molera, H. C. Behr, L. Heynemann and E. L. Ransome.

Several mechanical appliances used in engineering were exhibited and described by the members. Mr. Vischer described the Slide-rule; Mr. Specht described the Goldschmid aneroid; the others were surveying instruments of novel construction. Mr. Thomas Tennent described and exhibited a sextant with an attachment for an artificial horizon.

The following amendments to the Constitution and By-Laws were proposed:

The undersigned, Members of the Technical Society of the Pacific Coast, in good standing, move the following Amendments to the Constitution:—

1. To strike out Article XII, and to substitute the following article: "The Board of Directors shall consist of a President, two Vice-Presidents, a Treasurer, a Secretary, and six Directors, to hold office as follows: The President, Secretary and Treasurer for one year, (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of this article for two consecutive years); the Vice-Presidents for two years, and the Directors for three years, and no Vice-President and no Director shall be eligible for immediate re-election to the same office on the expiration of the term for which he was elected. At each annual meeting, a President, one Vice-President, two Directors, one Secretary and one Treasurer shall be elected, and the time of office shall continue until the adjournment of the meeting at which their successors have been elected.

Vacancies in the Board of Direction may occur by death or resignation, or the Board may by a majority of all its members declare the place of any officer vacant, upon his failure for six months from inability or otherwise, to attend the meetings of the board, or perform the duties of his office. All vacancies shall be filled by the appointment of the Board of Direction, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed, provided that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the board shall constitute a quorum, but business may be transacted at a regularly called meeting of the board, at which less than a quorum is present, subject to approval of the board, subsequently given in writing to the Secretary, and recorded by him in the minutes.

2. Article XIV. Strike out the word, "Vice-President," and substitute the words, "one of the Vice-Presidents."

3. Article XIII. Strike out the words, "The majority of the Board of Direction shall constitute a quorum."

4. Article XIX. Substitute for the words, "The third Saturday of January," and read, "Three weeks after the regular meeting of the month of January."

AUG. J, BOWIE, JR.
GEO. J. SPECHT.
H C. BEHR,
LUTHER WAGONER.
JAS. D. SCHUYLER.

AMENDMENT TO BY-LAWS:

Add to Article VIII. "SEC. 7. Copyrights of all papers, communicated to and accepted by the Executive Committee, shall be vested in the Society, unless otherwise agreed between the Board of Direction and the author. The Society is not, as a body, responsible for the statements of facts or opinions advanced in papers or discussions at its meetings; and it is understood that papers and discussions should not include matters relative to politics or purely to trade.

AUG. J. BOWIE, JR.
GEO. J. SPECHT.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXIX.

VOLUME III.—JANUARY, 1886.

A STATEMENT OF PHYSICAL CONDITIONS AFFECTING PACIFIC COAST HARBORS, WITH SOME REFLECTIONS.

By GEO. H. MENDELL, M. Tech. Soc.

Read January 8, 1886.

All of our seacoast harbors are barred by a cordon of sand which lies in front or seaward of the entrances and connects the shores on either side. Through this cordon there are one or more navigable channels, usually bounded on either side by sands upon which there is little depth of water, and upon which the sea habitually breaks, even in calm weather.

These bars or cordons are formed by the action of the sea, and not by deposition of earthy material contributed by interior currents.

The channel depth over the bar is a minimum, being generally considerably less than the depth found inside of the bar. From the bar, the bed of the ocean slopes away quite rapidly seaward and more gently inward.

The depth of water in the bar channel determines the value of a harbor by fixing the drafts and classes of vessels which can enter safely. The largest vessels find easy entrance to San Fran-

cisco at any stage of tide, a circumstance not true of any other port on our Pacific coast.

The depth on the San Francisco bar remains practically constant, except so far as affected by the diurnal variations in the level of the sea produced by the tide. This is not generally true as to all harbor entrances. On the contrary, an acquaintance with charts of the entrances of different harbors bearing different dates, demonstrates a general variation in low water depth and alignment of the bar channels. Some will be found at one date to be commodious, and at another date to be tortuous, shoal and difficult of navigation. In some cases, a single storm proves sufficient to change the circumstances to a degree such as to make previous acquaintance with the place, a snare. In other cases the changes are more gradual and the entrances appear to have a cycle of phases recurring after a period of years to preceding conditions.

The fluctuations of depth are often considerable, a channel of four fathoms degenerating to a depth of two fathoms or less. While these changes are in progress the interior channels remain comparatively unaltered, or at least maintain their navigable character without great variation.

We may classify these harbors in two groups. First, those which maintain the bar channels practically unaltered in depth and alignment from year to year; and, secondly, those which undergo noticeable alteration in these respects year by year or more frequently.

San Francisco and San Diego form the first class; the second includes all remaining entrances. Some of the circumstances which impress upon harbor entrances a character of permanence or the reverse are hereinafter mentioned.

We have also a considerable number of ports or roadsteads distinguished from harbors in not being inclosed by land. These ports are bights resulting from irregularities in the coast line. The entrances to these roadsteads are not obstructed by bars.

The forces which by interaction upon the bed and shores of the ocean, affect the commodiousness and navigable value of bar channels, are the drainage prism of the harbor—tidal and plu-

vious—the direction and strength of currents, channelwise and littoral, the direction and force of winds and also of waves produced by storms, near or remote.

The drainage prism for all of our harbors is mainly tidal, the land drainage being secondary to or insignificant when compared with the tidal volume. This is not only true of California, where the rainfall is small and fitful, but also of the Oregon coast, where there is an unusually heavy precipitation of rain.

The principal rivers of California are the Sacramento and the San Joaquin. In the autumn, the aggregate outflow of these two rivers is at times not more than 6,000 cubic feet per second. They have a season of freshet in the spring, while the snow on the Sierra is melting when the aggregate discharge may be about 100,000 feet per second; and there is usually a winter freshet, which occasionally becomes a flood, when for a short time, the rivers may deliver two or even three hundred thousand feet per second. Whatever these discharges may be, and, it is not here attempted to state them in any other form than that of approximation, it can readily be shown that the daily tidal complement of this harbor is largely in excess, even when the land drainage of the smaller streams discharging into San Francisco Bay, is included.

The tidal area tributary to the Golden Gate is 440 square miles excluding the estuaries of the rivers and the littoral marshes standing at the level of ordinary high water mark, and overflowed only at spring tides. The average fall of the large ebb, one in each day, is at San Francisco about five feet, six or seven tides in each month giving a fall of six feet. At Ravenswood, between this city and San Jose, the fall of the tide is 2.6 feet more than here, and at Mare Islsnd it is 1.3 feet more than at San Francisco. The general fall over the tidal area is therefore more than five feet. We omit from the calculation of area the marshes, the sloughs with which they are intersected, and the estuary or tidal portions of the rivers. If these be included, the tidal area will exceed 740 miles. It will readily appear from these premises, that the average duty of the ebb current effecting this change of level, supposing the bays to be completely emptied, must be quite three million cubic feet per

second, or for the period of maximum action of the ebb, more than six million cubic feet per second. In spring tides, the outflow is considerably more. It is probably the case, that the more distant area not being lowered in time, does not directly contribute its full quota to the outflow. Yet making all allowance that may be due for this deduction, it still remains that the landward drainage finding its way through the Golden Gate, is for the greater part of the year insignificant as compared with the volume contributed by the tide. Even a disastrous flood, which might bring down 400,000 cubic feet of water per second for twenty-four hours, could not half equal the volume which the tide supplies and removes each day in the year. During the average stages of the rivers the flow can hardly be one-tenth of the tidal volume. This daily ebb and flow of tide equals in volume the ordinary daily discharge of the Mississippi counted several times over, and is approximately equal to its maximum flow.

The tide plays a part nearly as important at the entrance of the Columbia River, which drains some 200,000 square miles of territory, and has a flood discharge approximately estimated at one million cubic feet per second. The estuary of the Columbia has an area of more than 200 square miles, or rather less than one-half the tidal area of this Bay. The mean rise and fall of the tide, however, exceeds that at San Francisco in the ratio of 5 to 3. The tidal discharge is estimated to be about one million cubic feet per second, which is about the outflow of the summer freshet. In the autumn, the backwater discharge is reduced to less than 100,000 cubic feet per second, and in a good stage of the river the flow varies from two hundred to three hundred thousand cubic feet per second.

The daily tidal complement is exceeded by the back water drainage only for a short time during the period of freshet, while for the remainder of the year the tidal contribution exceeds the land drainage in a proportion of 5 to 1, varying to 2 to 1.

In San Diego harbor the land drainage is at all times insignificant, and the conservative force may be regarded as purely tidal, with an approximate expenditure in the ebb of 150,000

to 160,000 cubic feet per second. The daily contribution of the flood tide acting for twelve hours is equal to the daily flow of the Sacramento River when in freshet. The ebb at Humboldt Bay restores to the ocean about 100,000 to 110,000 cubic feet per second. The land drainage here is not important as an aid to the tidal forces.

Illustrations might be continued, embracing Coos, Yaquina and Shoalwater Bay, Gray's Harbor, Umpqua River, and other instances.

It will be apparent from this statement that it is to the beneficent influence of the large tide which visits our coasts we are indebted for the harbors through which the commerce of the Pacific passes. If this tide, like that in the Gulf of Mexico, had a rise of one foot merely, instead of five or more feet, which characterizes our tides, our condition as to facilities of external commerce would, indeed, be pitiable. No engineering device could enable so feeble an ebb to adequately resist the destructive action of the westerly waves, which then must practically close our harbor entrances with sand. If there were no tide, there would be no harbors. Even the great Columbia River, with its flood discharge of a million cubic feet per second, might not be able to maintain throughout the year the entrance depth required for deep sea vessels.

Our own fine entrance would be closed by a line of sand beach, through or over which a feeble trickle would demonstrate the existence of a back-water drainage, but over which no vessel could ever hope to pass. San Diego, which may be said throughout the year to be independent of land drainage, would be closed, and, indeed, from San Diego to the Strait of Juan de Fuca there would be a weary stretch of inhospitable coast, unbroken by harbor, and nearly everywhere inaccessible by reason of heavy surf.

The exceptions would be in the roadsteads, where vessels, being protected from the northerly winds during the summer months, might receive and discharge cargoes, but under circumstances of considerable difficulty. During the winter months these anchorages are unsafe, owing to exposure to southerly winds. No great commercial interest could grow up under such unfavorable conditions.

This state of affairs might be remedied in part by conversion of roadsteads into harbors by artificial constructions, projected to protect from southerly winds and seas. The excessive cost of constructions required to protect sufficient areas, if it did not prevent the building of harbors, would at least defer and delay the works, to the great retardation of our internal development.

The tidal prism of a harbor depends upon two circumstances, namely: the area flooded and the rise of the tide. The latter element not only varies at any place from day to day, or from neap to spring, but there is in addition a diurnal variation in height which is peculiar, and which results in giving two unequal high waters in each day, and two low waters of different levels. High water and low water are, therefore, not exact terms. A plane of mean low water is assumed by the coast survey, to which soundings are reduced. It is the mean level of the lower of the two daily low waters. The low water of spring tides may be one or two feet below mean low water. The diurnal inequality of the tide is attributed to the effect of the declination of the moon, and it disappears when the declination is zero, at which time the two high waters become equal, as do the two low waters.

The order of recurrence of levels is this, namely: Beginning at the plane of lowest water, the tide rises to the small high water, then ebbs, reducing the level partially—that is, not so low as the initial level,—then floods to high water large, and finally ebbs to the lowest water. The second ebb here described voids a much greater volume than the first ebb, and more than either of the two flood tides accumulates. The phenomenon is this: that it requires two floods, nearly, to supply the prism of tide which the last ebb discharges. Hence, the stronger velocities are found on this ebb. Inasmuch as the clearing of channels is, by reason of its concentrative character, more due to the ebb than to the flood, the occurrence of phases just described appears to be favorable to maintenance of depth in channels.

The rise of the tide is found to vary from port to port, and to have a progressive increase north of San Francisco in some proportion to the increase in latitude, giving to the coast of Oregon

rises decidedly greater than those on the coast of California. The following are the means of rise and fall for the points named, as stated in Coast Survey publications: San Francisco, 3.6 feet; San Diego, 4.1 feet; Humboldt Bay, 4.4 feet; Coos Bay, 5.1 feet; Yaquina Bay, 5.6 feet, and Columbia River, 6.1 feet.

The means result from an average of all tides. The rise and fall for the larger tide of the day is considerably more than the mean, and near the phases of new and full moon, the variation is still greater. Indeed, the mean rise and fall as stated conveys no idea as to the maximum, which at San Francisco is fully 8 feet, at the Columbia River 12 feet or more, and in the inlets of Puget Sound 16 or 18 feet.

The entrance of San Francisco is the single example of two permanent headlands. Generally there is one rocky headland, the other head being the end of a strip of sand, to the presence of which the existence of the harbor is due. Humboldt Bay is an instance where both heads are sand-spits.

The enclosed character of these harbors where one or both heads are sand is due to the development, by wind, wave and current, of sand-spits extending across what was originally merely a bight in the shore line. The spit, where formed, included between it and the shore a strip of water, which in time became the tidal area of the existing harbor. If a reversal of force should remove the spit, the harbor would recur to its original condition—to be a bight in the shore line.

Where the heads are sand-spits, they are, as a rule, unstable. The currents may erode them, or the waves striking them obliquely may wear them away. An instance is the north spit or head at entrance of Humboldt Bay, which was carried away in eight months, 1881 and 1882, for a linear distance of 2,000 feet, losing 45 acres in area and about one million cubic yards of sand. Since that time the whole, or nearly the whole, has been restored.

The existence of permanent heads is a very favorable feature. The presence of unstable heads is correspondingly unfavorable. Changes in bar channels are apt to accompany changes in the heads, by which the width and cross-sections of the entrance are made to vary. The effect is not only unfavorable by the varia-

tion produced in the path and effective velocity of the current, but a wearing away of the spit may place at the disposal of the waves an enormous additional volume of sand, made liable to redeposition in places unfavorable to navigation. The excellent entrance at San Francisco is in part due to the permanent shores which bound it. San Diego, with a settled bar channel, has, however, a low sand headland on the south, which, however, is quite stable. It is protected by its position being covered from the sea by the protrusion of the rocky headland, Point Loma, on the other side; and its safety is also in part due to the infrequency of storms in this latitude.

The Columbia River has the basaltic cliff of Cape Disappointment for its northern head. The south head, Point Adams, is low and sandy, and is subject to considerable variation in extent and position.

One of the most important and difficult engineering desiderata in the improvement of these entrances is to give permanence to the sandy spits which form their shores.

The sand-spits already described, as developing enclosed harbors, and the long stretches of sand filling bights all along the Pacific Coast, are interesting objects of study in regard to their position, their mode of formation and the source from which the sands are derived. The general tendency of these deposits is to straighten the coast line. As a rule a sandy coast is nearly straight. The capes and points are worn away by the heavy waves that beat upon them, and the detritus is carried by currents, finding places of deposit in positions where the currents become reduced, which are in the bights or retired portions of the coast line.

The great enemy of coast harbor improvements is the breaking wave developed in the ocean it may be near at hand or at some remote point within the uubroken sweep of the whole width of the Pacifie, and propagated to expend its force upon our shores. This force is not only destructive of all constructions exposed to its action, but it forms the bars that lie in front of our harbors. Unresisted, it would entirely close the entrances by a bank of sand rising above high-water mark. If there were no great breaking waves, all our entrances would be less subject

to change in depth and alignment, or if there were no masses of sand to be displaced, the same result would obtain. Under the conditions that exist, the position and depth of bar entrances may be taken to represent the balance between the force of the outflow of water which tends to conserve channels, and the force of the sea which tends to obliterate them. Ever varying as these respective forces are, within limits greater or less, so varies the channel which represents the resultant of their combined and opposing efforts.

The conserving force is the more steady and persistent. Day by day and night by night the everflowing tide clears a path for itself, while the hostile force manifests itself in less continuous and more spasmodic efforts.

Something like a measure of the conserving force has already been given for a number of harbors, and it remains to state what is known of the magnitude of the wave force, which in our present state of knowledge must be given in terms not as specific as could be desired.

A measure of this force is the depth in which the oscillations of the particles of a wave or swell of the ocean are converted by the resistance of the bottom into motion of translation. The top of the wave moving with greater velocity than the lower portion lying near the bottom, the phenomenon of breaking is manifested by the rapid projection of the wave, as though it were discharged from an enormous gun. The force of the breaking wave is clearly an increasing function of its depth. The unusual depths in which the phenomenon occurs is a demonstration of the unusually destructive character of the wave.

The presence or absence of mud on the bottom of the ocean is usually accepted as evidence, in the first case, that the bottom has not been disturbed, and in the latter, that it has been disturbed. Mud settles only in quiet waters, and the ease which it is taken up by water in motion makes its presence or absence a delicate test of disturbance.

An inspection of the charts of this coast will discover that mud is seldom recorded as found in depths of ten fathoms, and frequently it is not found in even greater depths. A fair inference is that waves frequently break in ten fathoms. If the in-

ference needs to be corroborated by personal testimony, there is an abundance of intelligent statement available to maintain that waves frequently break in eight and in ten fathoms. This evidence it is impossible to discredit. A less probable but possibly a true statement is made by reliable parties that breaks have been seen in fifteen and even in seventeen fathoms.

The seas here are thought to be heavier than are found elsewhere, unless it be off the two south continental capes and in the Indian Ocean.

So far as evidence goes, the wave force is greater to the north than to the south of this port. The waves generally come from the southwest, and from that direction to west. The heaviest seem not to be due to storms near the coast, but to be propagated from a remote origin in the ocean. The great depth of the Pacific favors the transmission of waves from a distance.

These masses of water armed with great velocity and endued with a working power proportional to its square, are capable of displacing quantities of sand easily understood to be enormous, but not capable of estimate. Fortunately, their periods of action are generally short, lasting but a few days at a time, on this part of the coast, and less to the southward, but more to the northward, on the Oregon coast.

The southwest winds, to which storms of adjacent origin are due, prevail during the winter season, and the severity of the southerly storms is known to increase to the northward.

The northerly and westerly winds which prevail through the greater part of the year do not produce waves of great breaking force, and if, as sometimes happens, the largest waves visit us in the summer, they are due to storms which may have blown near the Asiatic shores.

Another oceanic element which has an influence upon our bar channels, and which needs to be considered in any project for their improvement, is the circulation of the waters of the sea, particularly as they result in developing a littoral current along the front of the harbor. This current, combined with or masked by the tidal flow and ebb, may have a definite and constant direction, or it may be feeble, uncertain and difficult to recognize. What information we have on the subject is due rather to

casual experience of mariners than to systematic observation and study, these never having been undertaken.

It seems to be established that an oceanic stream from the Indian Ocean, called the Japan current, passes in a northerly direction along the shores of Japan, thence to near the Aleutian Islands, reaches the Pacific Coast near the latitude of 50°, and moves down the coast to a point about Cape St. Lucas, diverging there to the westward to complete the continuity of the circulation. Whatever this current may be, it is well known that during the summer and generally through the season of northerly winds, there is a decided current down the coast and a quite noticeable eddy in the opposite direction close to the points and in the bights of the coast. During calm weather and during the prevalence of southerly winds, it seems that the eddy current is less noticeable or that its direction is changed from a northerly to a southerly direction. It is hardly possible, however, with the information at hand, to make an accurate general statement of these conditions.

The influence of a northerly eddy is apparent in the habitual direction of the channels at some bar entrances. Coos Bay entrance is an illustration. The usual direction of the channel over the bar is west of north going out and east of south as you enter. This direction appears to be a resultant of the ebb current, which makes to the west, and of the littoral current or eddy, which follows the shore to the north. During the winter, when southerly weather prevails, and the eddy current is either reduced in strength or reversed in direction, the channel sometimes takes a new position, bearing west to a vessel sailing out, or even to the south of west.

It may be interesting to know the area in cross-section of interior channels in different materials which are maintained by given tidal volumes, when there is no great disturbance due to waves. It will be seen that there is little uniformity in these cross-sections. This information has been obtained for several of the harbors mentioned, with rocky, hard or sandy bottoms, and it enables us to give an approximate statement of the apparent mean velocity of the ebb tide in these cases.

The mean velocity is hardly an indication of the maximum,

which we can readily understand to be twice the mean, but which in particular instances has been found to be three or four times the mean. It is to be remarked, however, that a current in practice never occupies the whole of the cross-section of a channel. On its borders there is commonly found a reverse or eddy current, and it is known from observation that surface and bottom currents may be at the same moment in opposition. The actual mean velocity must, therefore, be in excess of the apparent velocity. While these circumstances must affect in unknown degree the value of the approximations here given, yet it appears that these estimates have some value in fixing our ideas, or in marking a step in investigation.

San Francisco harbor, which we may estimate to discharge on an ebb tide nearly three million cubic feet per second, has a low water cross-section at its throat, the Golden Gate, [Fort Point to Lime Point] of 902,000 square feet, with a maximum depth of 69 fathoms. The cross-section at the heads, [Point Boneta to Point Lobos] at low water, is 1,101,615 square feet, with a maximum depth of 25 fathoms. The channel, [Black Point to Alcatraz] is 422,222 square feet; from Alcatraz to Angel Island, is 699,854, and from Angel Island to the mainland, at Peninsula Point, is 354,548. Adding the last three, we have a total low water cross-section of 1,476,824.

The bottom on first and smallest section is defined on chart as rocky. The section at the heads is rocky, pebbly and sandy, and the section by the islands of the harbor is classed as hard bottom in most places.

The bar of this harbor, measured on its crest from the north shore to the south beach, is about 14 miles in length. Taking a section on this line, we have low water depths from 10 fathoms under Point Boneta, to 3.5 fathoms with sandy bottom. The low water area of this section is 2,439,000 square feet. To recapitulate, the Golden Gate section is 902,000 square feet; the Point Lobos, 1,101,615; the islands section, 1,476,824, and the bar section, 2,439,000 square feet. The corresponding apparent mean velocities will vary in inverse proportion from about one to three feet per second.

The cross-section of the Columbia River just before it debouches

from the heads, is at low water about 450,000 square feet, with a maximum depth of 45 feet, with sandy bottom, and the mean tide section corresponds to a mean velocity of about 2 feet per second. The limits of variation of low water depth on the bar are about 18 and 27 feet. The depth is usually found between limits of 19 and 22 feet. The mean rise and fall of the tide being 6 feet, the high water depth is usually 26 to 28 feet.

The San Diego cross-sections, inside the heads, average about 80,000 square feet, and correspond to a mean velocity of something less than 2 feet per second. The low water depth on the bar varies little from 21 feet, which is equivalent to 25 feet at ordinary high water.

The volume of water in motion and its velocity being approximately ascertained, are the measure of the conserving force in our harbors. The working power of this current, theoretically, is proportional to the second power of its velocity.

A diminution of velocity resulting from a decrease of the tidal prism may impair the working force with an accelerated ratio.

This element, the conserving force, although constantly and necessarily undergoing loss from action of nature, which by the force of gravity is continually decreasing tidal areas, comes, nevertheless, partially under human control, to the extent that commercial or industrial interests encroach. These encroachments may be limited with propriety to their minimum limit, when they occur in positions that by occupation inflict injury. All portions of a tidal area or prism are not equally valuable in their conserving influence, and it may well be that a particular area can be embanked without appreciable diminution of useful force, whereas the same loss of volume differently situated might work serious injury. The rule is in this respect, that the water which escapes during the last half of the ebb is more valuable than the portion which makes up the earlier outflow.

It therefore behooves the commercial interests of our ports to have all encroachments upon tidal areas scientifically considered, in order that the probable injury, if any, can be ascertained and guarded against.

Considerations of this kind are not likely to attract much at-

tention, or to have much influence on men's minds in the activities of new communities, which have enough in the present to occupy attention without anticipating the future, and to whom a small present good more than counterbalances an evil of any magnitude, the occurrence of which is not to happen in their day and generation.

The force of the waves and the enormously destructive power of a sea breaking in 10 fathoms of water, are on the other hand beyond our control. These waves must ever break upon our sandy shores and displace at will the volumes of sand that may be exposed to their efforts. This consideration makes it imperative to preserve the tidal influence, which alone can be relied to resist injurious changes, or to restore a channel.

The ends sought in improvement of bars are to give permanent alignment and adequate depth to the channels. The volumes of water contributed by the tide are generally sufficient to maintain convenient channels, and it only needs that these volumes shall be controlled and directed along permanent lines to ensure the desired depths.

The problem is thus reduced to the establishment of permanent headlands, in suitable positions, and the difficulty lies in making secure, the necessary constructions. In some instances it is possible to arrange so that the sand, moved by wave or current, is itself made into a jetty, and being protected by artificial means, in turn is made to protect the constructions from the blows of the waves.

The force of the latter indicates the desirability of keeping exposed structures low, and in the general case this is probably the best policy, although it sacrifices necessarily in some degree the control of the tidal current which it is desired to direct. A compromise of this kind founded on a full understanding of the conditions, may be necessary to afford a practical advantage, not the possible maximum, at a practicable cost.

A structure rising only to half tide will permit the breaking wave to pass over it, and will thus escape the greater part of its destructive force, while at the same time it serves to control and direct that portion of the ebb tide which observation shows to be most active in deepening the channel section.

A construction built up only to low water is, of course, subject to a minimum of exposure, while at the same time it exercises a decided and appreciable influence in directing the ebb current.

The difficulty of securing permanence to constructions resting upon a sandy bottom and exposed to powerful destructive influences of current and wave, will readily be understood to be considerable, and as yet there is little experience in these operations on the Pacific Coast; but it is probable that the Columbia River and other instances of improvement will soon be undertaken, which will afford interesting examples of contest with forces yet but vaguely estimated.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

XXX.

VOLUME III.—JANUARY, 1886.

KUTTER'S FORMULA.

By P. J. FLYNN, M. Tech. Soc.

Read January 8, 1886.

Kutter's formula for feet measures is—

$$V = c\sqrt{rs} \quad - \quad - \quad - \quad - \quad - \quad (1)$$

where

$$C = \frac{41.6 + \frac{1.811}{n} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{n}{\sqrt{r}}} \quad - \quad (2)$$

In this formula and in what follows—

$V =$ velocity in feet per second.

$C =$ co-efficient of mean velocity.

$S =$ fall of water surface (h), in any distance (l), divided by that distance $= \frac{h}{l} =$ sine of slope.

$R =$ hydraulic mean depth in feet = area of cross section of pipe or conduit or channel in square feet divided by its wetted perimeter in lineal feet.

D = diameter of pipe or conduit.

N = the natural co-efficient, the value of which depends on the nature and condition of the bed of the channel through which the water flows, or in other words its degree of roughness.

In that admirable and useful work, *Molesworth's Pocket Book of Engineering Formulæ*, a modified form of Kutter's formula for pipe discharge is given, in which the value of

$$C = \frac{181 + \frac{.00281}{s}}{1 + .026\left(41.6 + \frac{.00281}{s}\right)} \quad - \quad - \quad (3)$$

For facility of reference I will call this equation Molesworth's Kutter (3), and equation (2) Kutter's formula (2). No mention is made by Molesworth of the value of n, that is, as to whether the formula is intended to apply to pipes having a *rough* or a a *smooth* inner surface. An investigation will, however, show that his formula is accurately applicable to *only one* diameter, that is, to a diameter of one foot, and with the value of $n = .013$.

The value of the term $\frac{n}{\sqrt{r}}$ in formula (2) is given by Molesworth in formula (3) as a *constant* quantity, whereas, in fact it is a *variable* quantity, its value, with the same value of n, changing with every change in the hydraulic mean radius or diameter of pipe.

Now, assuming the value of n taken by Molesworth to be = .013, and substituting this value for n in formula (2), we have

$$C = \frac{41.6 + \frac{1.811}{.013} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}}$$

and

$$\therefore \quad C = \frac{181 + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}} \quad - \quad - \quad (4)$$

but by Molesworth's Kutter (3)

$$\frac{.013}{\sqrt{r}} = .026$$

$$\therefore \sqrt{r} = 0.5$$

$$r = .25$$

$$\text{and} \quad d = 1$$

If we substitute in formula (4) for $\sqrt{r}$ its value 0.5, we have—

$$C = \frac{181 + \frac{.00281}{s}}{1 + .026\left(41.6 + \frac{.00281}{s}\right)}$$

which is Molesworth's Kutter.

It is, therefore, apparent that no matter what the value of n may be, Molesworth's Kutter (3) does not give the same results as Kutter's formula, as it gives a *constant* co-efficient of velocity c, for all diameters having the same slope and the same value of n.

Kutter's formula (2) has certain peculiarities which are wanting in Molesworth's Kutter, and an investigation will show that Molesworth's Kutter differs materially from Kutter's formula, and that its application, except to one diameter, is sure to lead to serious error. I will briefly explain. In what follows $n = .013$.

1. By Kutter's formula (2) the value of c, or the velocity, changes with every change in the value of r, s or n, and with the *same slope* and the same value of n, the value of c increases with the increase of r, that is, with the increase of diameter. It is on this variability of its co-efficient to suit the different changes of slope, diameter and lining of channel that the accuracy of Kutter's formula depends.

By Molesworth's Kutter a change in the diameter, other things remaining the same, does not affect the value of c. With the same slope the value of c is *constant* for all diameters.

As an instance, with a slope of 1 in 1,000—

	6 Inches Diameter. $C =$	20 Feet Diameter. $C =$
By Kutter's formula (2)	69.5	146.0
By Molesworth's Kutter (3)	85.3	85.3

It will thus be seen that the value of c by Kutter's formula (2) when $s = .001$, has a large range from 69.5 to 146, showing an increase of 111 per cent. from a diameter of 6 inches to a diameter of 20 feet. In this case, Molesworth's Kutter gives a *constant* co-efficient of 85.3, and this co-efficient applies to all diameters with a slope of 1 in 1,000.

It will be further found that Molesworth's formula gives the value of c, and, therefore, the value of the velocity and discharge, too high for diameters less than one foot, and too low for diameters above one foot, and the more the diameter differs from one foot the greater is the error. In these respects it follows the errors of the old formulæ.

2. According to Kutter's formula (2) the value of c increases with the increase of slope for all diameters whose hydraulic mean depth is less than 3.281 feet—one metre— and with a hydraulic mean depth greater than 3.281 feet, an increase of slope gives a diminution in the value of c.

The small table given herewith given shows this.

	12 Feet Diameter.		20 Feet Diameter.	
	1 in 1,000.	1 in 40.	1 in 1,000.	1 in 40.
Molesworth's Kutter, $c =$	85.3	86.9	85.3	86.9
Kutter's formula, $c =$	137.7	137.9	146.0	145.7

It will be seen that by Kutter's formula, when $r = 3$ feet, that is, less than 3.281 feet, an increase in the slope from 1 in

1,000 to 1 in 40 causes a slight increase in the co-efficient, but when r is 5 feet, that is, more than 3.281 feet, the same increase in the slope causes a slight diminution in the value of c.

By Molesworth's Kutter, when $r = 3$ feet an increase in the slope from 1 in 1,000 to 1 in 40 causes a greater proportional increase in the co-efficient than Kutter gives, and when $r = 5$ feet the value of the co-efficient does not diminish with the increase of slope, but, on the contrary, it increases with the increase in slope, and its value is the same as when $r = 3$ feet.

3. By Kutter's formula (2) when the hydraulic mean depth is equal to 3.281 feet (one metre), the value of c is *constant* for all slopes, and is $= \frac{1.811}{n}$ which in this case $= \frac{1.811}{.013} = 139.31$

Let $r = 3.281$ feet, and, therefore, $\sqrt{r} = \sqrt{3.281} = 1.811$, substitute this value in formula (2) for $\sqrt{r}$ and we have

$$C = \frac{41.6 + \frac{1.811}{n} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{n}{1.811}}$$

and

$$\therefore\ C = \frac{1.811}{n} \text{ and when } n = .013$$

$$C = 139.31.$$

This is the only instance, I believe, where Kutter's formula (2) gives a *constant* co-efficient with a change of slope. By Molesworth's Kutter, on the contrary, the value of c changes with every change of slope when $r = 3.281$ feet.

It is evident that Molesworth's formula was adopted in order to simplify the application of Kutter's formula (2), but its simplification is of no practical use as it gives very inaccurate results. As shown above, with the exception of its application to one diameter, the formula is not Kutter's, although in appearance bearing a resemblance to it. However, a modification of Kutter's formula can be made, simpler in form than even Molesworth's Kutter, and giving results near enough for all practical purposes to those obtained by the use of the more complicated Kutter formula (2).

The value of C in Kutter's formula (2) with a slope of 1 in 1,000 and $n = .013$, is thus expressed:

$$C = \frac{41.6 + \frac{1.811}{.013} + \frac{.00281}{.001}}{1 + \left(41.6 + \frac{.00281}{.001}\right)\frac{.013}{\sqrt{r}}}$$

and

$$\therefore \quad C = \frac{183.72}{1 + 44.41 \times \frac{.013}{\sqrt{r}}} \quad - \quad - \quad - \quad (5)$$

The following table will show the value of the co-efficient c for several slopes and diameters according to formulæ:

	Molesworth's Kutter (3) $C =$	Kutter's Formula (2) $C =$	Formula (5) $C =$
6 in. diam. slope 1 in 40	86.9	71.5	69.5
6 " " " 1 in 1000	85.3	69.5	69.5
4 ft. " " 1 in 400	87.2	117.0	116.5
4 " " " 1 in 1000	85.3	116 5	116.5
8 " " " 1 in 700	85.8	130.5	130.5
8 " " " 1 in 2600	82.9	129.8	130.5

This table shows the close agreement of formula (5) with Kutter's formula (2), and it also shows the inaccurate results obtained by the use of Molesworth's Kutter (3).

The first column of this table shows that a formula with a *constant* value of $c = 85$, that is,

$$V = 85\sqrt{rs} \quad - \quad - \quad - \quad - \quad (6)$$

will give results differing in an extreme case, only $2\frac{1}{2}$ per cent. from Molesworth's Kutter, and in the greater number of cases, differing only about one per cent.

The second column of the table shows the wide range of the co-efficient c, by Kutter's formula (2), from 69.5 to 130.5 to suit the different changes in the hydraulic mean depth and slope.

The objection to the old formulæ was that they gave velocities too high for small pipes and channels, and too low for large pipes and channels. The following table will show that the same inaccurate results are obtained by the use of Molesworth's Kutter (3).

	Velocity in Feet per second by		
	Molesworth (3)	Kutter (2)	Formula (5)
6 in. diam. slope 1 in 40	4.86	4.00	3.89
6 " " " 1 in 1000	0.95	0.78	0.78
4 ft. " " 1 in 400	4.36	5.85	5.83
4 " " " 1 in 1000	2.70	3.68	3.68
8 " " " 1 in 700	4.59	6.97	6.97
8 " " " 1 in 2600	2.30	3.60	3.62

This table shows that there is a wide difference between the velocities obtained by Molesworth's Kutter (3) and Kutter's formula (2), and it further shows that for the slopes usually adopted in practice for pipes, sewers, conduits, etc., that it is for slopes not flatter than 2 feet per mile, or 1 in 2640, formula (5) will give velocities that for all practical purposes may be considered as almost identical with the velocities obtained by Kutter's formula (2). The difference is generally less than one per cent., and it seldom reaches three per cent.

Mr. L. D'A. Jackson, C. E., in his *Hydraulic Manual,* and Mr. R. Hering, C. E., in a paper read before the Am. Soc. C. E., in 1878, extend the range of materials to which the different values of n adopted by Kutter apply.

A table of the value of n for different materials, compiled from Kutter, Jackson and Hering, is herewith given, and this value of n applies also in each instance to the surfaces of other materials equally rough.

$n = .009$. Well planed timber, in perfect order and alignment; otherwise, perhaps .010 would be suitable.

$n = .010$. Plaster in pure cement; planed timber; glazed, coated or enamelled stoneware and iron pipes; glazed surfaces of every sort in perfect order.

$n = .011$. Plaster in cement with one-third sand, in good condition; also, for iron, cement and terra cotta pipes, well jointed and in best order.

$n = .012$. Unplaned timber when perfectly continuous on the inside. Flumes.

$n = .013$. Ashlar and well laid brickwork; ordinary metal; earthenware and stoneware pipe in good condition, but not new; cement and terra cotta pipe not well jointed nor in perfect order; plaster and planed wood in imperfect or inferior condition; and generally the materials mentioned with $n = .010$, when in imperfect or inferior condition.

$n = .015$. Second class or rough-faced brickwork; well dressed stonework; foul and slightly tuberculated iron; cement and terra cotta pipes with imperfect joints and in bad order; and canvas lining on wooden frames.

$n = .017$. Brickwork, ashlar and stoneware in an inferior condition; tuberculated iron pipes; rubble in cement or plaster, in good order; fine gravel, well rammed, $\frac{1}{3}$ to $\frac{2}{3}$ inches diameter; and generally the materials mentioned with $n = .013$ when in bad order and condition.

$n = .020$. Ruble in cement, in an inferior condition; coarse rubble, rough set, in a normal condition, coarse rubble, set dry; ruined brickwork and masonry; coarse gravel, well rammed, from 1 to $1\frac{1}{3}$ inches diameter; canals with beds and banks of very firm, regular gravel carefully trimmed and punned in defective places; rough rubble, with bed partially covered with silt and mud; rectangular wooden troughs with battens on the inside two inches apart.

$n = .0225$. Coarse, dry-set rubble in bad condition.

The accuracy of the results by Kutter's formula depends on

the proper selection of the value of n for the surface of the material over which the water flows.

Again referring to the simplified form of Kutter's formula (5); if, in this equation, we call the numerator on the right hand side of the equation K for any value of n, we have

$$C = \frac{K}{1 + 44.41 \times \frac{n}{\sqrt{r}}}$$

$$\text{and } V = \left\{ \frac{K}{1 + 44\ 41 \times \frac{n}{\sqrt{r}}} \right\} \sqrt{rs} \quad - \quad - \quad (7)$$

In the following table the value of K is given for the several values of n already referred to.

	n	K	
	.009	245.63	
	.010	225.51	
	.011	209.05	
	.012	195.33	
	.013	183.72	
	.015	165.14	
	.017	150.94	
	.020	134.96	
	.0225	124.90	

If, therefore, in the application of formula (7) within the limits of n as given in the table, and within the limits of slope of 1 in 2640, as already explained, we substitute for n and K their values found on the same line in table, and also the value of $\sqrt{r}$ from the table given below, we have a simplified form of Kutter's formula.

For instance, when $n = .011$ and $D = 2$ feet, we have

$$V = \left\{ \frac{209.05}{1 + \left(44.41 \times \frac{.011}{.707}\right)} \right\} \times \sqrt{rs} \quad (8)$$

TABLE GIVING VALUE OF $\sqrt{r}$.

Diameter in		$\sqrt{r}$	Diameter in		$\sqrt{r}$
Feet.	Inches.		Feet.	Inches.	
0	5	0.323	2	6	0.790
0	6	0.354	2	9	0.829
0	7	0.382	3	0	0.866
0	8	0.408	3	3	0.901
0	9	0.433	3	6	0.935
0	10	0.456	3	9	0.968
0	11	0.479	4	0	1.000
1	0	0.500	4	3	1.031
1	1	0.520	4	6	1.061
1	2	0.540	4	9	1.089
1	3	0.559	5	0	1.118
1	4	0.577	5	3	1.146
1	5	0.595	5	6	1.173
1	6	0.612	5	9	1.199
1	7	0.629	6	0	1.225
1	8	0.646	6	6	1.275
1	9	0.661	7	0	1.323
1	10	0.677	7	6	1.369
1	11	0.692	8	0	1.414
2	0	0.707	9	0	1.500
2	1	0.722	10	0	1.581
2	2	0.736	11	0	1.658
2	3	0.750	12	0	1.732
2	4	0.764	13	0	1.803
2	5	0.777	14	0	1.871

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME III — JANUARY, 1886.)

MINUTES OF MEETINGS.

REGULAR MEETING.

January 8, 1886.

President Mendell in the Chair.

Minutes of preceding meeting read and approved.

The following propositions for membership were made:

Gardner F. Williams, proposed by Aug. J. Bowie, Jr., Geo. J. Specht and C. G. Yale.

Irving M. Scott, proposed by Aug. J. Bowie, Jr., L. L. Robinson and W. R. Eckart.

John B. Hobson (non-resident), proposed by Charles F. Hoffmann, Ross E. Browne, F. Von Leicht.

Col. Geo. H. Mendell read a paper, "Statement of Physical Conditions affecting Coast Harbors, with some reflections."

The following amendment to the By-Laws was read and adopted:

Article VIII. "SEC. 7. Copyrights of all papers, communicated to and accepted by the Executive Committee shall be vested in the Society, unless otherwise agreed between the Board of Direction and the author. The Society is not, as a body, responsible for the statements of facts or opinions advanced in papers or discussions at its meetings; and it is understood that papers and discussions should not include matters relative to politics or purely to trade.

A paper on "Kutter's Formulæ," by P. J. Flynn, was submitted by title for printing.

Mr. Bowie offered an amendment to the proposed amendments which had been submitted, but it was ruled out of order, on the ground that amendments to Constitution could only be considered at the annual meeting.

Mr. Wheeler also offered an amendment.

A general informal discussion ensued concerning amendments to the Constitution.

The Secretary was finally, on motion, instructed to print, not only amendments, but the original article to be amended and the suggestion offered at the meeting, and send them to members before the annual meeting.

In the matter of collecting funds for furnishing the new rooms, Mr. Robinson moved an assessment of $5.00 on each member of the Society.

Mr. Molera amended that an assessment of $1.50 be levied on each member.

Mr. Bowie moved that an assessment of $2.50 be levied on each member.

Mr. Gutzkow moved that a further request for voluntary subscriptions be made, which motion was carried.

ANNUAL MEETING.

January 16, 1886.

President Mendell in the Chair.

The tellers appointed to count the ballots cast for officers of the Society for 1886, reported the election of the following:

President, Col George H Mendell, U. S. A.; Vice-President, George J. Specht; Secretary, Charles G. Yale; Treasurer, G. W. Piercy.

Board of Direction—Aug. J. Bowie, Jr., G. W. Dickie, E. J. Molera, G. F. Allardt, E. C. Burr.

The report of the Board of Direction was read by the Secretary, and ordered spread on the minutes.

SAN FRANCISCO, January 16, 1886.

To the Members of the Technical Society of the Pacific Coast:

GENTLEMEN—In accordance with the terms of the Constitution, the Board of Direction desire to submit a brief report and some estimate of probable expenses for the year.

The membership of the Society remains about the same as it was at this time last year. Some members have moved away or resigned, and the new members elected have about kept up the number. We have elected during the past year 11 resident members, 2 non-resident and 2 associate members, and now have a total of 135 members in good standing.

We have expended during the past year, as per Treasurer's report, $1,525.04. These expenditures were as follows:

Printing Transactions	$575 26
Engraving	219 00
Circulars, cards, etc	135 95
Rent	180 00
Salary of Secretary	275 00
Commissions on collections	51 64
Stationery, postals, etc..	33 65
Miscellaneous	11 60
Postage	42 94

We have expended, in fact, more than was received from dues for the current year, back dues collected having made up the deficiency.

The uncollected dues are small, all the members now paying up more regularly than during our first year.

For part of the year our rent was $20 per month, but latterly $10 per month, and, although the new rooms are $20 per month, the Board can in other ways effect an economy which will keep these expenses about the same as the $10 rate for the rooms.

We expect this year to decrease the amount of expenditures for engravings, but it is difficult to say what the publication of the Transactions will cost. The circulars, cards, etc., which cost $135 last year, will cost much less this year, as we now have a good supply on hand.

The fees and dues for 1885 were $1,188, and we expect fully that amount, if not more, for this year. We shall, of course, have to limit our expenditures accordingly.

We have established exchanges with 57 societies, whose proceedings we now receive. This is giving us a nucleus for a library, which will increase the usefulness of the Society for its members.

It is to be hoped that each one will try and induce at least one friend to join the Society this year. Our membership can be increased materially if those who now belong will bring the Society to the attention of others interested in the technical branches.

The renting of a special room brings no increase of expense to the Society, for the reasons mentioned; and by reducing expenditures for engravings, circulars, etc., we expect to be able to carry on the Society for the year without indebtedness.

The Treasurer's report was received and ordered spread on the minutes.

To the Officers and Members of the Technical Society of the Pacific Coast:

GENTLEMEN—I submit the following as the Treasurer's report for the year ending December 31st, 1885.

RECEIPTS.

Cash from former Treasurer	$268 40	
Fees and dues for 1884	155 00	
Fees and dues for 1885	1,188 50	
Total receipts		$1,611 90

DISBURSEMENTS.

Printing Transactions	$575 26	
Engravings	219 00	
Printing circulars, cards, etc	135 95	
Rent of Hall	180 00	
Salary of Secretary	275 00	
Commissions on Collections	51 64	
Postage stamps	42 94	
Stationery, postals, etc	33 65	
Miscellaneous	11 60	
Total expenses		$1,525 04
Cash on hand		$86 86
Uncollected dues for 1885 (about)		$60 00
Liabilities for same (about)		25 00
Balance (about)		$35 00

It will be seen from the foregoing statement that the amount of dues and fees collected for the year 1885 is about $340 less than the expenses for same, and that, but for the surplus on hand at the beginning of the year, and the back dues collected for 1884, there would be a deficit of about the amount stated.

Respectfully submitted,

G. W. PERCY, Treasurer.

At the previous meeting of the Society, the Secretary was instructed to send to members not only the proposed amendments to the Constitution, previously printed, but the changes suggested at the meeting of January 8th.

These proposed amendments were as follows:

To amend Article XII of the Constitution as follows:

To strike out Article XII, and to substitute the following article: "The Board of Direction shall consist of a President, two Vice-Presidents, a Treasurer, a Secretary, and six Directors, to hold office as follows: The President, Secretary and Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of this article for two consecutive years); the Vice-Presidents for two years, and the Directors for three years; and no Vice-President and no Director shall be eligible for immediate re-election to the same office on the expiration of the term for which he was elected. At each annual meeting, a President, one Vice-President, two Directors, one Secretary and one Treasurer shall be elected, and the time of office shall continue until the adjournment of the meeting at which their successors have been elected.

Vacancies in the Board of Direction may occur by death or resignation, or the Board may, by a majority of all its members, declare the place of any officer vacant, upon his failure for six months from inability or otherwise, to attend the meetings of the Board, or perform the duties of his office. All vacancies shall be filled by the appointment of the Board of Direction, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed, provided that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Board shall constitute a quorum, but business may be transacted at a regularly called meeting of the Board, at which less than a quorum is present, subject to approval of the Board, subsequently given in writing to the Secretary, and recorded by him in the minutes.

The amendment to this Section XII, offered by Mr. Bowie, January 8th, was to strike out the first paragraph of the proposed amendment to Article XII; also to strike out last two lines of second paragraph, and substitute as follows:

The Board of Direction shall consist of nine Directors, one of whom shall be the President of the Society and two others shall be respectively First and Second Vice-Presidents. The Directors shall be elected by written ballots of a majority of votes at the annual meeting. They shall be the Trustees of the Society.

At the first annual meeting subsequent to the adoption of this amendment, three of the nine Directors elected shall be chosen for three years, three for two years, and three for one year. And at each subsequent annual meeeting, three Directors shall be elected to serve three years.

The Secretary and Treasurer shall be elected by ballot in the same manner and in the same time, to hold office for one year. Both or either of them may or may not be members or Directors of the Society.

The President and Vice-Presidents shall be elected at the annual meeting by ballot, for one year, or until their successors are elected.

Article XVI of the Constition to be amended as follows:

Strike out the word, "Vice-President," and substitute the words, "one of the Vice-Presidents."

Article XII of the Constitution to be amended as follows:

Strike out the words, "The majority of the Board of Direction shall constitute a quorum."

Article XIX of the Constitution to be amended as follows:

Substitute for the words, "The third Saturday of January," and read, "Three weeks after the regular meeting of the month of January."

Mr. Wheeler's proposed amendment to this section was as follows:

For the 3d sentence of Article XIX, substitute the following: "The annual meeting for the election of officers and hearing the annual report shall be held at the same time as the regular meeting of the month of January of each year."

All of the above amendments were discussed by Messrs. Bowie, Hanscom, Manson, Dickie, Wagoner, and Schuyler.

Mr. Hanscom moved, and Mr. Schuyler seconded, the indefinite postponement of the amendment offered to Article XII, which motion was carried.

All the other amendments were voted down, with the exception of that originally proposed to Article XIX, which was adopted as follows:

In Article XIX, substitute for the words "the third Saturday of January," and read, "Three weeks after the regular meeting of the month of January."

REGULAR MEETING.

February 12, 1886.

Mr. G. W. Percy was elected President *pro tem.*

Minutes of preceding meeting read and approved. The tellers announced the election of the following members:

Gardner F. Williams, Irving M. Scott, John B. Hobson, William G. Raymond and B. Salazar.

Wm. G. Goodrich was proposed for membership by Wm. Minto, G. F. Allardt and F. Von Leicht.

The Secretary read a communication from John Richards, describing the result of visits among the machine shops and foundries in the Eastern States and in England.

Mr. Allardt reported on behalf of the Finance Committee that an examination of the books of the Treasurer had been made, and that the accounts were correct.

Mr. Vischer spoke of the desirability of increasing the library by the addition of various published reports. The matter was referred to the Executive Committee.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME III.—MARCH, 1886.)

COMPOUND TRANSITION CURVES.

By W. G. RAYMOND, M. Tech. Soc.

Read March 5, 1886.

In presenting to you a few tables to aid in the location of easement curves, it has been thought best to give the deduction of the equations from which they were calculated, and to explain the use of the tables. Nothing new is attempted as the ground has been covered in other ways, and partially so in the method herewith presented, and these tables are far from complete; but they contain enough quantities for the ready location of all ordinary cases and for the solution of the ordinary problems arising in this particular part of railroad location.

It is assumed that a "one degree" curve gives a sufficiently easy transition from tangent to curve, and hence the first chord of the transition or easement curve is that of a one degree curve. The second is of a two degree curve, third, of a three degree curve, etc. The chord points are on a curve of a cubic parabola, and hence the super-elevation of the outer rail may begin at the beginning of the curve and attain its maximum amount at the point where the transition curve joins the main curve. In the figure let the main or central curve be of degree D, a whole number. If located without easement the "B. C." falls at A' and the tangent is $V'A'$. To substitute for this curve one of

the same radius, but eased at the ends by a transition curve it is necessary to throw the curve in along the central line $V' O'$ a distance $P' P = A' B$.

B, then, becomes the new $B. C.$ for the simple curve located from the tangent $B. V.$ parallel to $A' V'$.

The transition curve is $A E$, and in the figure is supposed to consist of three arcs, thus uniting it with a "four degree" curve.

We wish to find—

1. The angle $B O E = d$.
2. The distances $F E = t$.
   $A F = l$.
   $B A' = P P'$
3. The tangent distance of the new curve—

$$V' A = Te.$$

It is supposed that the chords of the transition curve are equal. If n be the number of chords and D the degree of the main curve, then it is evident from the foregoing description that—

$$n = D - 1$$

The sum of the angles subtended by the chords of the transition curve is equal to the angle $B O E = d$.

If c be the length of the chord in fractions of a station, as, for chord of fifty feet, $c = \frac{1}{2}$, etc. Then—

$$d = c\left(1 + 2 + 3 + 4 + \text{etc., to } (D - 1)\right)$$
$$= \frac{c}{2}\left(D^2 - D\right)$$

$A F$ is the latitude of the curve $A E$, and $F E$ is its departure; hence—

$$\left.\begin{array}{l} a.\ FE = t = 100c\left(\text{Sin}\ \frac{c}{2} + \text{Sin}\ \frac{4c}{2} + \text{Sin}\ \frac{9c}{2} + \text{\&c. Sin}\ \frac{n^2 c}{2}\right) \\ b.\ AF = l = 100c\left(\text{Cos}\ \frac{c}{2} + \text{Cos}\ \frac{4c}{2} + \text{Cos}\ \frac{9c}{2} + \text{\&c. Cos}\ \frac{n^2 c}{2}\right) \end{array}\right\}(1)$$

For small angles equation (1) a may be written—

$$t = 100\ c\ \text{Sin}\ \frac{c}{2}\left(1 + 4 + 9 + \text{etc., n}^2\right)$$

And if we take the difference between the chord and its latitude we have, instead of (1) b,

$$100\,nc - l = 100\,c \text{ vers } \frac{c}{2}\left(1 + 16 + 81 + \&c.\ n^4\right) \quad \text{(approximately.)}$$

KE is the departure of the main curve for angle d, and BK is its latitude.

$$\left.\begin{array}{l} KE = t' = R \text{ vers } d \\ BK = l' = R \sin d \end{array}\right\} \quad (A)$$

R being the radius of the main curve.

We have then—

$$\left.\begin{array}{ll} & A'C = t - t' \\ a. & B\ C = (t-t') \tan \frac{1}{2} I \\ b. & A'\ B = P'P = (t-t') \sec \frac{1}{2} I. \end{array}\right\} \quad (2)$$

I being the central angle of the whole curve.

$$\begin{aligned} Te &= A'\ V' + A\ A' \\ &= R \tan \tfrac{1}{2} I + A'\ B' + B'\ A \\ &= \left\{R + (t-t')\right\} \tan \tfrac{1}{2} I + (l-l') \quad (3) \end{aligned}$$

To locate the transition curve by deflection angles, it is necessary to know the angle FAE.

$$\tan\ FAE = \frac{t}{l} \qquad (4)$$

The "long chord" of the transition curve may be computed from the formula—

$$C = \frac{t}{\text{Sin } FAE} \qquad (5)$$

For use in the field, tables of the values of d, t, t', l, l', $(t-t')$, $(l-l')$ angle $FAE = e$ and C may be computed for different values of c and D, and such tables for a large number of cases are herewith presented, numbered in the order in which they would be most used. The values of C in the table may be in error in the last figure. It is thought that the other tables are correct within 1 in the last place. With these tables, the labor of computing and locating these curves is but little greater than that required for the simple curves, and there would seem to be

no good reason for omitting them in any case of radius less than 5730 feet.

To illustrate the use of the tables we will take an example:

It is required to locate a 7° curve with a transition curve having chord lengths of 25 feet, I being 30° at sta. 2760.

From tables (1), (2) and (3) we have—

$$d = 5^\circ - 15'$$
$$t - t' = 1.52'$$
$$l - l' = 74.93'$$

Whence—

$$Te = 820.54 \tan 15^\circ + 74.93.$$

and we have the "*B.C.*" at sta. 2757 + 80.14. Setting the instrument at this point, we turn from the tangent successively the angles given in the line $c = \frac{1}{4}$ in table (4), the chainmen measuring twenty-five feet chords around the curve.

For 1st chord	$e =$	07′.50
" 2d "	$e =$	18′.75
" 3d "	$e =$	35′.00
" 4th "	$e =$	56′.25
" 5th "	$e =$	1° 22′.50
" 6th "	$e =$	1° 53′.75

This brings us to the point of compounding with the main curve.

Setting the instrument at this point, and having sighted to the "B. C.," turn off an angle equal to $d - e$, and the instrument will be in the line of the tangent to the main curve, which may then be run. The length of the main curve is known from its central angle being equal to $I - 2d$.

Having located the whole of the main curve, set the instrument at its end, and from the tangent at that point turn the angle $d - e$, and on the line thus obtained run a distance $= C$ for $n = 6$ as found in table (5) $= 149.95'$. Bring the instrument to this point from which as many points on the closing transition curve as may be desired, may be located as in the beginning.

It being desirable to locate each "station" on the curve, the deflections may be found from table (4) by interpolation as for ordinary plusses in simple curves.

If the tangents have not been run out, and it is not necessary to begin the curve at the exact point, it may of course begin at an even station as in other cases.

If D be a mixed number, as for instance $7\frac{1}{2}$, then n is the whole number without the fraction, in this case 7, and as the tables are only for D equal a whole number less than eleven, the values of t' and l' with those for $t—t'$ and $l—l'$ would need to be computed, either from formulas (A) or from formulas—

$$t_1' = \frac{R_1}{R} t'$$

$$l_1' = \frac{R_1}{R} l'$$

in which t_1' is t' for the $7\frac{1}{2}°$ curve.

R_1 " R " " $7\frac{1}{2}°$ "
R " R " " $7°$ "
t' " t' " " $7°$ "

The subscripts referring to the same curves in the second formula.

In this case the transition from the easement curve to the main curve is not quite regular, but is sufficiently so for practice.

If desired, the curve may be located by offsets from the tangent, the values of t and l being used. In many cases, only the points A and E need to be located with the instrument, the others being put in afterwards by measurement. In projecting a location upon a preliminary map, the curve may be placed where desired, and the tangent drawn at a distance from the curve equal to ($t—t'$).

If deemed desirable, tables for angles to be deflected from the tangent at E to the various points on the transition curve might be computed. Time has been insufficient for such computation.

TABLE I.

Values of d for various lengths of chords when D and n =

$$\left(\text{Formula } d = \frac{c}{2}(D^2 - D)\right)$$

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1 = 100 ft.	1° 00′	3° 00′	6° 00′	10° 00′	.....	.....	.....	.....	.....
9-10 = 90 "	0° 54′	2° 42′	5° 24′	9° 00′	.....	.....	.....	.....	.....
4-5 = 80 "	0° 48′	2° 24′	4° 48′	8° 00′	.....	.....	.....	.....	.....
$\frac{3}{4}$ = 75 "	0° 45′	2° 15′	4° 30′	7° 30′	11° 15′	.....	.....	.....	.....
7-10 = 70 "	0° 42′	2° 06′	4° 12′	7° 00′	10° 30′	.....	.....	.....	.....
$\frac{2}{3}$ = $66\frac{2}{3}$ "	0° 40′	2° 00′	4° 00′	6° 40′	10° 00′	.....	.....	.....	.....
3-5 = 60 "	0° 36′	1° 48′	3° 36′	6° 00′	9° 00′	12° 36′	.....	.....	.....
$\frac{1}{2}$ = 50 "	0° 30′	1° 30′	3° 00′	5° 00′	7° 30′	10° 30′	14° 00′	.....	.....
2-5 = 40 "	0° 24′	1° 12′	2° 24′	4° 00′	6° 00′	8° 24′	11° 12′	14° 24′	.....
$\frac{1}{3}$ = $33\frac{1}{3}$ "	0° 20′	1° 00′	2° 00′	3° 20′	5° 00′	7° 00′	9° 20′	12° 00′	.....
3-10 = 30 "	0° 18′	0° 54′	1° 48′	3° 00′	4° 30′	6° 18′	8° 24′	10° 48′	13° 30′
$\frac{1}{4}$ = 25′ "	0° 15′	0° 45′	1° 30′	2° 30′	3° 45′	5° 15′	7° 00′	9° 00′	11° 15′
1-5 = 20′ "	0° 12′	0° 36′	1° 12′	2° 00′	3° 00′	4° 12′	5° 36′	7° 12′	9° 00′
1-6 = $16\frac{2}{3}$ "	0° 10′	0° 30′	1° 00′	1° 40′	2° 30′	3° 30′	4° 40′	6° 00′	7° 30′
1-10 = 10 "	0° 06	0° 18′	0° 36′	1° 00′	1° 30′	2° 06′	2° 48′	3° 36′	4° 30′

TABLE II.

Values of $(t - t')$ for various chord lengths when D and n =

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	0.44	1.75	4.36	8.71	.....	.....	.....	.....	.....
9-10	.35	1.41	3.53	7.06	.....	.....	.....	.....	.....
4-5	.28	1.12	2.79	5.58	.....	.....	.....	.....	.....
$\frac{3}{4}$	.26	0.98	2.45	4.90	8.57	.....	.....	.....	.....
7-10	.21	.86	2.14	4.27	7.46	.....	.....	.....	.....
$\frac{2}{3}$	.19	.78	1.94	3.87	6.78	.....	.....	.....	.....
3-5	.16	.63	1.57	3.14	5.49	8.77	.....	.....	.....
$\frac{1}{2}$	.11	.44	1.09	2.18	3.82	6.10	9.13	.....	.....
2-5	.07	.28	0.70	1.40	2.44	3.90	5.85	8.34	.....
$\frac{1}{3}$	.05	.19	.49	0.97	1.70	2.71	4.06	5.79	.....
3-10	.04	.16	.39	.79	1.37	2.20	3.29	4.69	6.45
$\frac{1}{4}$	.03	.11	.27	.55	0.95	1.52	2.29	3.26	4.48
1-5	.02	.07	.18	.35	.61	0.98	1.46	2.09	2.87
1-6	.01	.05	.12	.24	.42	.68	1.02	1.45	1.99
1-10	.01	.02	.04	.09	.15	.24	0.37	0.52	0.72

TABLE III.

Values $(l—l')$ for various chord lengths when D and n =

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	50.00	99.97	149.87	199.60	.....	.....	.....	.....	.....
9-10	45.00	89.97	134.90	179.70	.....	.....	.....	.....	.....
4-5	40.00	79.98	119.93	159.78	.....	.....	.....	.....	.....
$\frac{3}{4}$	37.50	74.99	112.43	149.81	187.05	....	.....	.....	.....
7-10	35.00	69.99	104.94	139.85	174.62	.....	.....	.....	.....
$\frac{2}{3}$	33.33	66.64	99.95	133.19	166.34	.....	.....	.....	.....
3-5	30.00	59.99	89.96	119.89	149.75	179.47	.....	.....	.....
$\frac{1}{2}$	25.00	49.99	74.97	99.98	124.89	149.72	174.42	.....	.....
2-5	20.00	40.00	59.99	79.95	99.90	119.80	139.64	159.39	.....
$\frac{1}{3}$	16.67	33.33	49.99	66.63	83.26	99.87	116.42	132.93	.....
3-10	15.00	30.00	44.99	59.97	74.94	89.90	104.81	119.69	134.51
$\frac{1}{4}$	12.50	25.00	37.49	49.98	62.46	74.93	87.37	99.79	112.17
1-5	10.00	20.00	30.00	39.99	49.97	59.95	69.91	79.86	89.79
1-6	8.33	16.67	25.00	13.33	41.65	49.96	58.28	66.57	74.85
1-10	5.00	10.00	15.00	20.00	25.00	29.98	34.97	39.96	44.93

TABLE IV.

Value angle e for various chord lengths when D and n =

$$\left(\text{Formula } \tan e = \frac{l}{l}\right) \quad \textit{Nearest 3 seconds.}$$

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	0° 30′.00	1° 15′.00	2° 20′.00	3° 44′.95	.....	.....	.....	.....	.....
9-10	0° 27′.00	1° 07′.50	2° 06′.00	3° 22′.50	.....	.....	.....	...	.....
4-5	0° 24′.00	1° 00′.00	1° 52′.00	3° 00′.00	.....	.....	.....	.....	.....
$\frac{3}{4}$	0° 22′.50	0° 56′.25	1° 45′.00	2° 48′.75	4° 07′.45	.....	.....	.....	.....
7-10	0° 21′.00	0° 52′.50	1° 38′.00	2° 37′.50	3° 50′.95	.....	.....	.....	.....
$\frac{2}{3}$	0° 20′.00	0° 50′.00	1° 33′.35	2° 30′.00	3° 39′.95	.....	.....	.....	.....
3-5	0° 18′.00	0° 45′.00	1° 24′.00	2° 15′.00	3° 18′.00	4° 32′.95	.....	.....	.....
$\frac{1}{2}$	0° 15′.00	0° 37′.50	1° 10′.00	1° 52′.50	2° 44′.95	3° 47′.40	4° 59′.85	.....	.....
2-5	0° 12′.00	0° 30′.00	0° 56′.00	1° 30′.00	2° 12′.00	3° 02′.00	3° 59′.95	5° 05′.85	.....
$\frac{1}{3}$	0° 10′.00	0° 25′.00	0° 46′.65	1° 15′.00	1° 50′.00	2° 31′.65	3° 20′.00	4′ 14′.95	.....
3-10	0° 09′.00	0° 22′.50	0° 42′.00	1° 07′.50	1° 39′.00	2° 16′.50	3° 00′.00	3° 49′.45	4° 44′.90
$\frac{1}{4}$	0° 07′.50	0° 18′.75	0° 35′.00	0° 56′.25	1° 22′.50	1° 53′.75	2° 30′.00	3° 11′.20	3° 57′ 45
1-5	0° 06′.00	0° 15′.00	0° 28′.00	0° 45′.00	1° 06′.00	1° 30′.80	2° 00′.00	2° 33′.00	3° 09′.95
1-6	0° 05′.00	0° 12′.50	0° 23′.35	0° 37′.50	0° 55′.00	1° 15′.80	1° 40′.00	2° 07′.50	2° 38′.30
1-10	0° 03′.00	0° 07′.50	0° 14′.00	0° 22′.50	0° 33′.00	0° 45′.50	1° 00′.00	1° 16′.50	1° 35′.00

TABLE V.

Values of "long chord" for various chord lengths when D and $n =$

$$\left(\text{Formula C} = \frac{t}{sin.} \right)$$

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	100.00	200.00	299.88	399.53	.....	.....	.....	.....	.....
9–10	90.00	180.00	269.90	359.60	.....	.....	.....	.....	.....
4–5	80.00	160.00	239.92	319.72	.....	.....	.....	.....	.....
$\frac{3}{4}$	75.00	150.00	224.93	299.77	374.40	.....	.....	.....	.....
7–10	70.00	140.00	209.94	279.81	349 52	.....	.....	.....	.....
$\frac{2}{3}$	66.67	133.33	199.96	266.51	332.91	.....	.....	.....	.....
3–5	60.00	120.00	179.97	239.94	299.67	359.26	.....	.....	.....
$\frac{1}{2}$	50.00	100.00	149.98	199.95	249.88	299.65	349.18	.....	.....
2–5	40.00	80.00	119.99	159.96	199.91	239.77	279.53	319.14	.....
$\frac{1}{3}$	33 33	66.67	100.00	133.30	166.63	199.87	233.06	266.17	.....
3–10	30.00	60.00	90.00	119.98	149.96	179.89	209.80	239.63	269.34
$\frac{1}{4}$	25.00	50.00	75.00	99.99	124.98	149.95	174.88	199 79	224.61
1–5	20.00	40.00	60.00	80.80	99.99	119.97	139.94	159.89	179.81
1–6	16.67	33.33	50.00	66.67	83.33	99.99	116 61	133.27	149.90
1–10	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	89.97

TABLE VI.

Values of t for various lengths of chords when D and $n=$

$$\left(\text{Formula } t = 100c \left(sin\,\frac{c}{2} + sin\,\frac{4c}{2} + sin\,\frac{9c}{2} + \&c.\ sin\,\frac{n^2c}{2} \right) \right)$$

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1 = 100 ft.	00.873	4.363	12.209	26.126	.....	.....	.....	.....	.....
9-10 = 90 "	.707	3.533	9.890	21.170	.....	.....	.....	.....	.....
4-5 = 80 "	.558	2.792	7.815	16.733	.....	.....	.....	.....	.....
$\frac{3}{4}$ = 75 "	.491	2.454	6.869	14.709	26.926	.....	.....	.....	.....
7-10 = 70 "	.428	2.138	5.984	12.815	23.463	.....	.....	.....	.....
$\frac{2}{3}$ = $66\frac{2}{3}$ "	.388	1.939	5.429	11.625	21.287	.....	.....	.....	.....
3-5 = 60 "	.314	1.571	4.397	9.418	17.250	28.493	.....	.....	.....
$\frac{1}{2}$ = 50 "	.218	1.091	3.054	6.542	11.985	19.807	30.416	.....	.....
2-5 = 40 "	.140	0.698	1.954	4.187	7.674	12.687	19.495	28.357	.....
$\frac{1}{3}$ = $33\frac{1}{3}$ "	.097	.485	1.358	2.909	5.331	8.815	13.550	19.720	....
3-10 = 30 "	.079	.393	1.100	2.356	4.318	7.141	10.979	15.982	22.296
$\frac{1}{4}$ = 25 "	.055	.273	0.764	1.636	2.999	4.960	7 628	11.107	15.502
1-5 = 20 "	.035	.175	.489	1.047	1.920	3.175	4.884	7.113	9.931
1-6 = $16\frac{2}{3}$ "	.024	.121	.339	0.727	1.333	2.205	3.392	4.941	6.900
1-10 = 10 "	.009	.042	.122	.262	0.480	0.794	1.221	1.780	2.486

TABLE VII.

Values of t' for various lengths of chord when D and $n=$

(Formula $t' = \text{R vers } d$.)

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	.436	2.618	7.848	17.415	.....	.....	.....	.....	.....
9–10	.353	2.120	6.358	14.112	.....	.....	.....	.....	.....
4–5	.279	1.675	5.025	11.155	.....	.....	.....	.....	.....
¾	.246	1.472	4.417	9.806	18.36	.....	.....	.....	.....
7–10	.214	1.283	3.848	8.544	16.00	.....	.....	.....	.....
⅔	.194	1.163	3.490	7.751	14.51	.....	.....	.....	.....
3–5	.157	0 943	2.827	6.279	11.76	19.72	.....	.....	.....
½	.109	.655	1.963	4.362	8.17	13.71	21.29	.....	.....
2–5	.070	.419	1.257	2.792	5.234	8.786	13.65	20.02	.....
⅓	.048	.291	0.873	1.939	3.635	6.105	9.489	13.93	.....
3–10	.039	.236	.707	1.571	2.945	4.946	7.689	11.29	15 85
¼	.027	.164	.491	1.091	2.046	3.436	5.343	7.846	11.02
1–5	.017	.105	.314	0.698	1,309	2.200	3.421	5.025	7.063
⅙	.012	.073	.218	.485	0.909	1.528	2.376	3.491	4.908
1–10	.004	.026	.079	.175	.327	0.550	.856	1.258	1.768

TABLE VIII.

Values of l for various chord lengths when D and $n=$

$$\left(\text{Formula } l = 100c\left(\cos\frac{c}{2} + \cos\frac{4c}{2} + \cos\frac{9c}{2} + \&c \cos\frac{n^2c}{2}\right)\right)$$

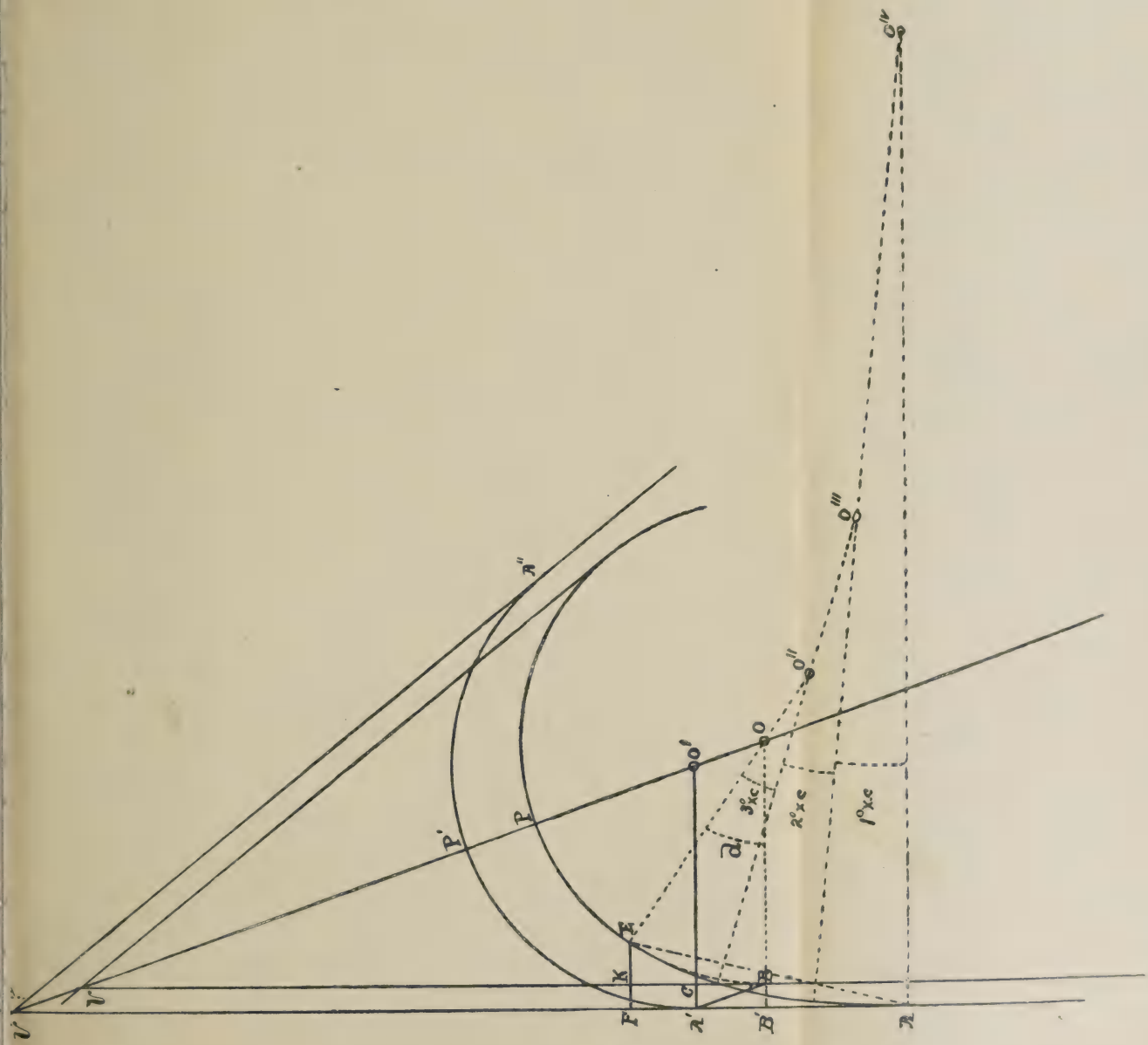
C	2°	3°	4	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	100.00	199.94	299 63	398.65	.....	.....	.....	.....	.....
9–10	90.00	179.95	269.73	359.02	.....	.....	.....	.....	.....
4 5	80.00	159.97	239.81	319.31	.....	.....	.....	.....	.....
¾	75.00	149.98	224.84	299.43	373.43	.....	.....	.....	.....
7–10	70.00	139.98	209.87	279.54	348.72	.....	.....	.....	.....
⅔	66.67	133.31	199.89	266.27	332.23	.....	.....	.....	.....
3–5	60.00	119.99	179.92	239.71	299.20	358.13	.....	.....	.....
½	50.00	99.99	149.95	199.88	249 59	298.97	347.83	.....	.....
2–5	40 00	80.00	119.98	159 91	199 76	239.45	278.86	317.87	.....
⅓	33.33	66.66	99.99	133.28	166.53	199.08	232.68	265.43	.....
3–10	30.00	60.00	89.99	119.96	149.90	179.77	209.52	239.10	268.43
¼	25.00	50.00	74.99	99.98	124.94	149.87	174.72	199.48	224.09
1–5	20.00	40.00	60.00	79.99	99.97	119.93	139.86	159.73	179.53
1–6	16.67	33.33	50.00	66.66	83.32	99.96	116.59	133.18	149.73
1–10	10 00	20.00	30.00	40.00	50.00	59.99	69.98	79.97	89.94

TABLE IX.

Values of l^1 for various chord lengths when D and n =

(Formula $l^1 = R \sin \underline{d}$)

C	2°	3°	4°	5°	6°	7°	8°	9°	10°
	1	2	3	4	5	6	7	8	9
1	50.00	99.97	149.76	199.05	.....	.....	.....	.....	.....
9–10	45.00	89.98	134.83	179.32	.....	.....	.....	.....	.....
4–5	40.00	79.99	119.88	159.53	.....	.....	.....	.....	.....
$\frac{3}{4}$	37.50	74.99	112.41	149.62	186.38	.....	.....	.....	.....
7–10	35.00	69.99	104.93	139.69	174.10	.....	.....	.....	.....
$\frac{2}{3}$	33.33	66.67	99.94	133.08	165.89	.....	.....	.....	.....
3–5	30.00	60.00	89.96	119.82	149.45	178.66	.....	.....	.....
$\frac{1}{2}$	25.00	50.00	74.98	99.90	124.70	149.25	173.41	.....	.....
2–5	20.00	40.00	59.99	79.96	99.86	119.65	139.22	158.48	.....
$\frac{1}{3}$	16.67	33.33	50.00	66.65	83.27	99.81	116.25	132.50	.....
3–10	15.00	30.00	45.00	59.99	74.96	89.87	104.71	119.41	133.92
$\frac{1}{4}$	12.50	25.00	37.50	50.00	62.48	74.94	87.35	99.69	111.92
1–5	10.00	20.00	30.00	40.00	50.00	59.98	69.95	79.87	89.74
1–6	8.33	16.67	25.00	33.33	41.67	50.00	58.31	66.61	74.88
1–10	5.00	10.00	15.00	20.01	25.01	30.01	35.01	40.01	45.01


V
V'
F
K
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C
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P'
P
A''
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O
O''
O'''
O''''
d
3°xc
2°xc
1°xc

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME III—MARCH, 1886.)

MINUTES OF MEETINGS.

REGULAR MEETING.

MARCH 5, 1886.

Vice-President Specht in the chair.

Minutes of preceding meeting read and approved.

The following propositions for membership were made:

Hamilton Smith, Jr., proposed by Geo. J. Specht, Aug. J. Bowie, Jr., and G. F. Allardt.

Louis Janin, proposed by Aug. J. Bowie, Jr., Chas. G. Yale and Geo. J. Specht.

Allexey W. Von Schmidt, proposed by G. H. Mendell, Aug. J. Bowie, Jr., and L. J. Le Conte.

Wm. Ashburner, proposed by Aug. J. Bowie, Jr., E. J. Molera and Geo. J. Specht.

Thomas Price, proposed by Aug. J. Bowie, Jr., Chas. G. Yale and G. F. Allardt.

Arthur F. Price, proposed by Aug. J. Bowie, Jr., Chas. G. Yale and G. F. Allardt.

Frank K. Zook, proposed by G. H. Mendell, Aug. J. Bowie, Jr., and L. J. Le Conte.

The following donations were received:

Map of Contra Costa County, from Wm. Minto; Map of Monterey County, from Geo. J. Specht; Map of Lake Tahoe, from F. Von Leicht; and profile of Mexican railroads, from Geo. J. Specht.

Wm. G. Raymond read a paper on "Compound Transition Curves."

Mr. Molera reported from the Executive Committee that informal meetings would be held every Friday evening at the rooms, except on the first Friday of each month, when the regular meeting takes place.

REGULAR MEETING.

APRIL 3, 1886.

Vice-President Specht in the chair.

The following were elected members: Louis Janin, Wm. Ashburner, A. W. Von Schmidt, Thomas Price, Arthur F. Price, Wm. W. Goodrich and Frank K. Zook.

John B. Clarke, Assistant Professor of Mathematics, University of California, was proposed for membership by Frank Soule, Wm. Ashburner and Chas. G. Yale.

Wm. T. Blunt, ex-Secretary of the Executive Board of the Civil Engineers' Committee on National Public Works, addressed the Society on the subject before the Committee, viz., the appointment of a Board of Public Works by the Government.

The thanks of the Society were voted to Mr. Blunt for his address.

On motion of Mr. Wagoner, the President of the Society was requested to appoint a committee of three to consider the question of "the appointment of a Board of Public Works by the Government."

The President subsequently appointed as such Committee Luther Wagoner, A. H. Payson and Marsden Manson.

Technical Society of the Pacific Coast.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

VOL. III.—MAY, 1886.

THE THEORY OF ORE CRUSHING.

By LUTHER WAGONER, Mem. Tech. Soc. P. C.

Read May 7, 1886.
Reprinted December, 1889. Revised and corrected edition.

The object of this paper is to discuss the laws that govern the reduction of minerals to a state of fine grains or dust, and to attempt to draw useful conclusicns from the same.

The literature upon the special subjects to be investigated is very meagre and of little practical application; there are some experiments upon the crushing strength by quiet pressure upon cubes of stone, and general remarks upon the result of stamp and roller work, in the various books relating to metallurgy. There is also an article by the writer in Eng. & Min. Jour., Jan. 26, 1884, in which the methods of investigation are partly described; the diagrams illustrating the article will be used in this paper.

Some of the ideas advanced are original and supposed to be new, and while the writer believes them to be true, he is aware that uncertainty must always attend any generalization from empirical laws; therefore he invites a full and fair criticism of any views advanced in this paper, to the end that the truth may be known.

THE OBJECT OF CRUSHING.

The object of crushing a mineral may be one of two general cases, as follows :

a. The production of grains of a definite size and of which the total surface of a unit mass shall be a minimum ; (concentration, roasting, etc.).

b. The production of grains of the smallest size and of which the total surface of a unit mass shall be a maximum.—(Dust, the pulverization of Gypsum, Portland cement, etc.).

Only case *a* will be considered.

The object of crushing an ore is to release some valuable component contained therein ; the component may be a metal, as gold or silver, etc. ; or a mineral, as pyrite, galena, etc. Whatever be the nature of the component, it is usually tolerably evenly distributed through the mass of ore. Hence the latter must be broken into pieces sufficiently small to release the enclosed valuable component. The surface of the mineral or metal is a natural cleavage plane, and if the rock be broken into small enough pieces the mineral will be almost wholly freed from the gangue. The limit of maximum size of the grains of gangue is always a matter to be determined by experiment. The size that will liberate enough mineral so as to leave the coarsest sizes commercially barren, is usually spoken of as crushing through some number of sieve or screen. For gold ores this usually ranges from twenty to sixty screen for wire cloth screens. Thus far the operation is a common one to every system, as the rock must be broken before anything can be done with it ; the product is technically known as pulp, and the word will be used to denote the condition of all the rock finer than some specified screen.

The second step is to separate the free mineral or metal from the pulp, and as the crushing is generally a wet operation, only the latter will be noticed.

The operation being a continuous one, the question of ore grains either held in suspension or moved by a current of water, is to be briefly noticed. The suspension velocity of an ore grain is, according to

Rittinger and others, said to be as the square root of the density in water and as the square root of the diameter, or—

$$V = a\sqrt{\text{diameter} \times \text{specific gravity} - 1}.$$

From the above it is plain that the size of the grain has a very important influence. The form of the grain, as known by experiment, may vary the result to the extent that the co-efficient a, in the above formula may range from one to three times in value. For these reasons the first part of this paper is devoted to the examination of the physical properties of the pulp.

Careful experiments made by the writer (see proceedings Tech. Soc. P. C. July, 1888) show that the above formula does not hold for grains of quartz of usual sizes dealt with and that it should be modified to the form of

$$V = 270 \frac{d^{\frac{3}{2}}}{\left(d + \frac{1}{1+d}\right)}$$

where V is the velocity in mm. per second of a vertical current of water that will hold in suspension a quartz grain whose least or sieve diameter is d: in the experiments d ranged from 0.06 mm. to 0.80 mm. The co-efficient 270 is for the average grain, but for particular forms will vary from 130 to 390. Pulp used was from N. Y. Hill Mine, Grass Valley, Calif. No. 4 Battery screen, crushed by wet stamping.

Suppose that a piece of rock be placed in a mortar and be subjected to repeated blows from a pestle; it is broken into smaller pieces; let this operation be continued until the mass of rock feels like dust or powder. What has happened? Feeling it between the fingers shows that some of the pieces are larger than others; it is next assorted by sieves and each lot weighed, the percentage calculated. This experiment can be repeated with substantially the same result as regards form of grains and their percentage. Let a number of grains, such as will difficultly pass a sieve, be taken for microscopic examination; this will show that there has been no alteration in the mean form of the grain from the upper limit of size down to 0.075 mm. 150 sieve. By means of a rising current of water this examination can be carried down to values as small as 0.01 mm. = ($\frac{1}{2500}$ inch), and without assorting, it can be seen

that no change in the general form of the grain occurs with decrease of diameter as small as .0005 mm. $= \frac{1}{50,000}$ inch. The most minute grains, if they be enlarged under the microscope, will appear almost like the ore as it left the rock-breaker. Therefore, dust may be defined as a collection of grains of the same form and different diameters. To more accurately examine the percentage, or the relation of quantity that exists between grains of different diameters, procure an accurate sample of pulp from a mill running on a clean, homogeneous ore; the sample should be an average of the regular work on the particular ore; the water should be filtered from the pulp and the latter dried.

To separate the pulp into different sizes, either water currents or sieves may be used; the latter are most convenient, and are sufficiently accurate. The trade numbers of sieves are in terms of meshes per linear inch, this does not convey any idea of the net aperture between the wires. To determine this, count the wires in a lineal inch or given space, and also measure the thickness of the wire; the difference is the net aperture of the sieve. In this way the writer determined the various brands of steel and brass wire-cloth in this market; and for Russia iron screens the thickness of the standard needles used for gauging the same was measured with a micrometer. The results are represented graphically in inches and metric system by Diagram 1.

Having carefully sifted a weighed lot of dried pulp, weigh the amount that remains upon each sieve; the dust that passes through the finest sieve should be estimated by difference, as there is usually a loss from one to three per cent. met with by reason of dust floating away in the air; calculate the percentage of each lot, and next construct a diagram like those of 2, 3, 4, that will represent the data graphically. To make this clear, the method of construction of curve A, Diagram 4, will be explained. The data is arranged as follows:

											%
Pulp	resting	on	20	mesh	= 0 %		Total	pulp	on	sieve,	0
"	"	"	30	"	43.3		"	"	"		43.3
"	"	"	50	"	29.5	+	43.3	"	"		70.8
"	"	"	57	"	5.3	+	70.8	"	"		76.1
"	"	"	100	"	7.1	+	76.1	"	"		83.2
"	"	"	120	"	4.8	+	83.2	"	"		88.0
"	"	"	150	"	4.2	+	88.0	"	"		92.2
"	passing		150	"	7.8	+	92.2	"	"		100.0

The final quantities are the percentages that would be obtained by sifting the whole pulp on any sieve. This value is taken for the ordinate y, and the net space or aperture of the sieve is the abscissa x, the points being set off, the initial and terminals are to be found, the initial point is $x = o$ and the terminal is $x =$ aperture of battery screen.

From an inspection of the diagrams it is seen that a unit mass of pulp is composed of grains of ore having a definite relation to each other in respect to size and of number. A statement of this relation would be the *law of crushing* for the particular ore under consideration.

These curves (Diagrams 2, 3, 4) do not show the law of crushing, *but they are the graphical representation of the integral of the equation of that law :* therefore the first differential co-efficient is the desired law. This is clear when it is remembered the percentage of pulp between any two diameters is the sum of the weights of all the grains between those diameters.

To find the first differential co-efficient, the principle $\frac{dy}{dx} =$ tangent of the angle that the curve makes with the axis X, may be used. In this case a parallel ruler is made tangent to the curve for any x, and the value of the tangent can be read directly on the line of Y. Sufficient points having been obtained in this manner, they are platted as $y = fx$. Curves a, b (Diagram 4), were constructed in this way.

If an equation can be found to represent the values of y in terms of x, it can be differentiated and the same result attained.

Having shown the nature and construction of these curves, let us revert to the pulp. What is it that gives it the feeling of smoothness characteristic of dust ? Clearly there has been no internal change, therefore it must be an external change, or a change in the surface ; but the form of the grain is also unchanged, hence the only possible change is in the amount of surface.

ON THE SURFACE OF THE PULP.

The surface of any grain may be expressed by $a\,x^2$, and its weight by $b\,x^3$, where a and b are general co-efficients. Let m denote the weight or volume of grains of the diameter x : then $\frac{m}{bx^3} =$ the number of grains

for the mass m, but the surface for one grain is a x^2, and $\frac{a\,x^2\,m}{b\,x^3} = \frac{a\,m}{b\,x}$; an equation that shows the surface will vary as the reciprocal of the diameter; but the amount of pulp for any diameter is known, hence the total surface for that diameter is known, provided that a and b are known.

ON THE WORK OF CRUSHING.

Experiments made on cubes of stone under quiet pressure, show that the crushing force varies nearly as the cross-section broken (Bauschinger), and the experiments of Gillmore show that for cubes of sandstone, ranging from one-quarter to four inches diameter, the crushing force is nearly as the 7-3 power of the diameter or side of the cube. None of these experiments appear to be of much comparative value for the following reasons. Work is the product of force and space; if the space is not known, the work is not known and results are not comparable. For either quiet pressure or impact, the work is divided into two parts, one of which appears as fractured surface, the other as heat, hence the useful work may be treated as an extension of surface.

This view is supported by the experiments quoted where the resistance is nearly as x^2, but the surface is also a function of x^2, where the stone is broken in few pieces. The quartz or ore may be assumed as homogeneous, and surface cannot be created without work expended in overcoming the cohesion of the molecules in some plane, and this is constant for a unit of section Therefore it may be written,

USEFUL WORK=FUNCTION OF THE SURFACE.

To discuss this mathematically, let the percentages passing any sieve be represented by a straight line (see curve *A*, Dia. 4); this curve is nearly a straight line, and the two curves show that if $y = ax^n$, that n may be more or less than one, therefore it may be one for some particular case. Then

$$y = ax, \text{ and}$$

$$\frac{dy}{dx} = a,$$

An equation that shows an equal weight of grains for any diameter is made; but the surface, as previously shown, is

$$s = \frac{1}{x}$$

Then the total relative surface between any two values of x being S, we have,

$$S = \int_{x1}^{x2} a\ x^{-1}\, d\ x = a \text{ Nap. log.} \left(\frac{x^2}{x^1}\right)$$

Solving this equation for the limits .001 and 1,000,* and tabulating the values, the following facts are shown :

For x,	0.001 mm.	to	$x_{,,}$	= 0.01 mm.	$S_{,}$	= a	.2.3026
" $x_{,}$	.001	to	x	= 0.10	$S_{,,}$	a	.4.6052
" x	001	to	x	1.00	$S_{,,,}$	a	.6.9078

From the above it appears that one-third of all the surface is included between the limits of x 0.001 and 0.01, or that $\frac{1}{100}$ of the finest pulp has one-third of the total surface, and that ten per cent. of the fine pulp has ⅔ of the total surface.

Similarly at the coarse end the surface between x .99 and 1 is only $S_{,,,,} = a$ .0085, or 270 times as much work is required to crush one per cent. of ore at the fine end, as to crush one per cent. at the coarse end.

Suppose the same law of crushing to hold, and let R equal the ratio of surface to weight between the limits $x = .001$ and any greater value of x; then $R = \frac{a \log x}{a\ x} = \frac{\log x}{x}$ an equation that shows the surface produced will be inversely as the aperture of the battery screen. To make the above more general, let any of the curves have the equation $y = a\ x^n$: then $\frac{d\ y}{d\ x} = n\ a\ x^{n-1}$, dividing by x and integrating

$$S = \int n\ a\ x^{n-2} d\ x = \frac{n}{n-1}\ a\ x^n$$

NOTE.—The lower limit $x = .001$ mm. is an arbitrary assumption, but supposed to be a practical value. The assumption of $x = o$ leads to an infinitely large amount for the surface, and hence is unwarranted. There is no ground for supposing that a smaller sized grain can be produced by varying the mode of crushing, or, in other words, if ore be stamped or rolled there is no reason known why the diameter of the smallest grains made by either process should differ ; therefore no serious error can arise in a comparison of results if the same minimum diameter be used in each case and the said value be a reasonable one.

$$\text{But } R = \frac{\frac{n}{n-1} a x^{n-1}}{a x^{n}} = \frac{n}{n-1} x^{-1} \qquad \text{or} \qquad \frac{\frac{n}{n-1}}{x}$$

which proves that if the law of crushing does not change, the work will be inversely as aperture of the battery screen.

ON THE RELATIVE SURFACE PRODUCED BY STAMPS AND ROLLERS.

The law of crushing must be a function of the force or blow that breaks the grain, and also of the rate of discharge, for in the first case such a blow can be given as will break the body into few or many pieces. The blow of a stamp being uniform, the number of pieces made by the blow will depend upon the size of the rock upon the die as well as the number of pieces of rock. Now, if the pulp cannot escape as fast as it is reduced to the size of the battery screen, some of it will be made smaller. The same remarks apply to rollers where the force is constant. If the stone is properly adapted to the space between the rolls, but few pieces will be made, and if dust be mixed with the coarse pieces, some of the dust will also be crushed finer.

There is no data to separate the influence of the discharge from the law of crushing ; but there can be no doubt that in two systems, where one crushes faster than it can discharge, and the other does not crush as fast as the screen will discharge the pulp, there will be a great difference in the quality of the pulp.

To illustrate these conditions, curves *A*, *B*, diagram 4, are introduced for discussion. Curve *A* is from pulp from the Tustin pulverizer, and *B* is from a stamp battery, both running on the same ore and screen. For the benefit of those unacquainted with the principle of the Tustin roller mill, reference is made to the sectional view in the drawing, Fig. 5. The scale is 1-28 of actual size. The rollers (10, 10,) are 18 inches long and 19½ and 14 inches diameter. They roll upon the shoes (11) and crush the ore. The pulp escapes through the slotted shoes on to the wire cloth screen on the outside of the cylinder (14). The sifting out takes place in the lower right hand quadrant. When crushing wet, water is admitted at (38) by a nozzle placed near the top of the outside case. There are eight sections of wire cloth, 18 by 18 inches=18 square feet of screen. The machine is practically the equal of six stamps, both running on 20 screen and the same ore, and it was discharging 1,000

pounds of quartz per hour. It revolves 20 times per minute, or 1,200 per hour. Hence 1000-1200 pounds of ore is screened over 18 square feet, or one pound of pulp has 15 square feet of screen to escape through. A stamp discharges 2.75 pounds per minute through an effective surface of about 72 square inches, or one pound of pulp passes through 0.182 square foot. The relative screen surface is thus seen to be 15-.0.182=82 to 1.

From the above it is clear that the Tustin is a machine having a crushing power less than its screening power. For this reason, the law of crushing by it should be constant and independent of the screen.

Discussion of Curves *A*, *B*, Diagram 4.

Curve *A* is nearly a straight line, and the equation $y=a\,x$ will nearly satisfy it, more accurately $y=90\,x+17.11\,x^{1.7}$. The differential coëfficient is

$$y=90+29{,}087\,x^{.7}$$

This divided by x and integrated between the limits

$x_{,}$=.001 mm. and $x_{,,}$=0.94 mm. is total relative surface S=

$$S=90 \text{ Nap. Log } 940+41.55\,(.94^{.7}-.001)^{.7}=656.$$

Curve *B* is plotted from the equation.

$$y=36 \text{ Nap. Log. } (100x+2.5)-33\,x^{\frac{3}{2}}-34{,}398.$$

The differential of this equation is

$$\frac{dy}{dx} = \frac{36}{(x+.025)} - 49.5\,x^{½}$$

Dividing by x and integrating there is

$$S=1440 \text{ Nap. Log. } \left(\frac{.025+x}{x}\right)-99\,x^{½}+C.$$

Note.—Both of the equations to curves *A*, *B*, are empirical, and it should be noticed that the origin of co-ordinates is taken at the upper left hand corner of the diagram as a matter of convenience in calculation.

This equation solved between the limits .001 and .940 gives S=4569 and the relative surface is 4560-656=6.95, or about 1 to 7.

The adoption of $x_{,}$=.01 as a lower limit would raise the ratio from the former to 1 to 4, but as many grains exist smaller than 0.001 mm., it is probably large enough, and nearer the truth than the latter assumption, and certainly near enough for the present purpose.

The next in order is to show the amount of power used in each system The power required to drive three Tustins was measured by the writer, using a Prony brake ; it was found equal to 3.98 H. P. for one machine at 20 revolutions per minute, the machines doing their normal work, or 11.92 H. P. for three machines—the power being measured from the counter shaft.

The power applied to each machine is about as follows :

For friction of the machine, gear, belts, tightener pulleys....	H. P.—1.30
Work lost due to unbalanced load.....	1.00
Friction of rollers between the end and sides and not doing any useful work, estimated at.....	.70
Work usefully applied.....	1.00
	H. P. 4.00

This estimate may be in error, either too large or too small, but not more than 15 per cent., as at least 2.60 H. P. can be readily accounted for as due to friction and unbalanced load, while it is very probable that friction must exist to the extent named without contributing to useful work.

For the stamps the H. P. is 750 pounds, falling 6 inches 90 per minute. Here the net work due gravity is assumed to be useful work, which for six stamps is 6.14 H. P. Dividing the relative surface by the work expended usefully,

$$\text{there is } \frac{4560}{6.14} = 740 \text{ and } \frac{656}{1.00} = 656.$$

These quantities are nearly enough in accord with each other to reasonably prove the proposition that the useful work applied will appear as surface. No account is taken of that portion of the work lost as heat, nor is any very great accuracy claimed for the above equations, because the laws of crushing are much too complex to be represented by simple equations, like those given.

But the above will serve to show that the greater part of the useful

work applied is consumed at the fine end of the pulp or in uselessly extending the surface; and the presentation of the above equations may serve a good purpose in directing thought to that most important and generally neglected question.

Is the Sliming of Ore Either Necessary or Beneficial?

Having shown the nature and amount of pulp for any diameter, and that there is no other change except the one of increased surface for diminishing diameters, it is a subject for inquiry, how the increase of surface affects the separation of the valuable component from the pulp. Experience has shown that the greatest difficulty encountered in ore dressing is the sliming of the ore. The coarse parts in general above 100 mesh are easily managed.*

The law of suspension velocity for bodies in water has been mentioned, but while it may be true for spheres of considerable magnitude, it certainly has no application to small grains.

The formula given on page 47 for the suspension velocity of quartz grains $V = 270 \dfrac{d^{\frac{3}{2}}}{d + \dfrac{1}{1+d}}$ for large values of d becomes $V = f.\, d^{\frac{1}{2}}$ and for small values of d it approaches nearly $V = f.\, d^{\frac{3}{2}}$. The denominator assumes that a certain quantity of water is attracted and adheres to the grain and thus becomes a part of it: in the above formula it is supposed that a part of this skin will be stripped away with increasing velocities:

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*Very loose and erroneous ideas prevail in regard to losses, especially by those who should know better. As an illustration, a person pans tailings after a good concentrator; he finds nothing in the pan; therefore there is nothing in the tailings. Now, if the concentrator can do better work than the pan, how can the pan save anything? Let any one try the experiment of pulverizing some marble dust, like average stamp pulp, and add to it some small quantity, say 2 per cent., of pyrites, that have been similarly crushed. Let the concentration be made and see if the amount added be recovered. If not, dissolve the gangue in acid, and there will be a residual composed of the lost pyrites. The finer the pulverization, the less will be recovered by concentration. Of course, an assay would show there was a loss, but when people cannot find anything by panning, they usually conclude there is nothing to find.

this is why the term $\frac{1}{1+d}$ is introduced. Practically ore grains greater than 3 mm. diameter follow the ordinary law of falling bodies, grains of sand 100 mesh to 20 mesh are nearly as the diameter, while for smaller sizes (slimes) the fall is according to some power of the diameter greater than 1. This is in accord with theory, for if the law of falling bodies held, a body infinitely small would fall, thus overcoming the viscosity or frictional resistance of the water, The cross sectional resistance of a body is as d^2 and its weight as d^3, but $\frac{d^3}{d^2} = d$, which shows that the weight per unit of resistance decreases directly as the diameter decreases; hence there must arrive a point where the resistance of the liquid will balance the body (permanent suspension). Either of the views leads to a change in the exponent for the ordinary formula $V = f\, d^{\frac{1}{2}}$.

Thus the phenomena of floured bodies, as gold, quicksilver, is easily shown to be due to no other cause than surface adhesion. To prove this, introduce some clean mercury into a chemically clean bottle containing some distilled water. After a brisk shaking the mercury will be floured. The probable effect of the surface adhesion is to coat or envelop the body with an external coat of water that moves with it, and thus acts two-fold by increasing the surface and decreasing the relative weight. The result is that such a body in any average current of water will be forever in motion produced by eddying action from the current.

There is also another aspect of this case, when the water is thick with fine grains of anything, as ore or clay. The bodies exert a mutual attraction, and give rise to viscosity of the liquid medium, and render the settlement of grains that would otherwise settle, more difficult. Every mill man knows the injurious effect of muddy feed water for the battery. Here the particles of clay are still angular bodies, but of extremely small diameter and great surface, by their mutual attraction rendering the water viscous or thick, the fine gold and quicksilver is carried away by the current. Hence the extension of surface will act injuriously in two ways, viz.: by depriving the body of its relative weight as compared to surface; by the mutual attractions between the

small grains and the liquid, preventing the settlement of small grains.* In the case of gold ores not containing sulphurets, it has been generally assumed that it is a matter of indifference how fine the ore is crushed, as no loss will occur by breaking up the grains to a very fine slime, and that no shearing or cutting of the gold takes place, owing to its malleability.

To determine this point, the following described experiments were made by the writer for the Fulton Foundry on the ores marked *A B C D*, Diagram 3. The Murphy's ore is from the Oro Plata mine, and is composed of a hard low grade quartz mixed with a large amount of clay. The latter is hydrauliced out, and the washed quartz is sluiced into the bins of the stamps and Tustins. The battery has no inside plates. The first gold lodging on the heads of the outside plates should be alike. To test this, a quantity of amalgam was cut off from the top of the plates, and the mercury removed by acid. Each lot was rubbed with the finger through a 150 mesh sieve, with the following result:

Tustin, coarser than 150 sieve, per cent	3.78
Stamps " " " " " "	1.76

The former in bulk appeared as a bright yellow—the latter as dark brownish yellow. Mr. F. B. Morse, the superintendent, informed the writer that the amalgam averaged as follows:

Tustins, amalgam retorts	30 to 35%
Stamps, " "	25 to 30%

or as a mean, 32½ % against 22½ %. This indicates that more surface exists, as the finer the gold grains the lower in value is the amalgam. As the ore is identical, the gold must have been cut up by the stamps or rather by the shearing and abrasive action of the quartz grains.

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*The managers of a large stamp mill in this State denied that any quicksilver was lost by flouring, and proved it by panning the tailings as they came from the mill, with the result of not a trace of floured quicksilver. The writer then placed a bucket under the discharge trough and allowed it to fill. After standing three minutes to settle, the top portion of the water was decanted into a clean pan, filling the latter to about one-third of its depth; next, clean water was added to fill the pan and the whole carefully "panned," adding clean water from time to time. The result was a long streak of floured quicksilver and two small pieces of amalgam.

In the case of curves *C*, *D*, the ore is from the Utica mine at Angels, Calaveras Co. Curve *D* shows the pulp from 900 pound stamps, at 85 per minute, falling 6 inches. The general milling result of this ore is, per ton :

Saved by amalgamation	$3.60
" " Duncan concentrator	.80
Lost in the tailings	4.60
Value per ton	$9.00

This ore, worked in the Tustin, gave for a lot of 2.1 tons, per ton.

Saved by amalgamation	$5.70
" " Frue Vanners	2.00
Lost in tailings	1.30
Value per ton	$9.00

Separation of the tailings by sieves and panning each size separately showed that the tailings contained 20 cents per ton in sulphurets and amalgam, leaving $1.10. A similar examination of the stamp tailings showed that the value of the sulphurets would be about $2.30 per ton Hence there would be $6.70 free gold.

Combining the above data, there is :

	Tustin.	Stamps.
Free gold saved, percentage of value	85	54
Sulphurets " " " "	87	35
Total value " " " "	85½	49 *

No other reason for this great difference can exist except that of sliming the pulp, and perhaps cutting up the gold to some extent. It should be remarked that this ore is a talcose slate mixed with quartzite, limestone and dolomite ; it is very easily slimed.

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* Subsequently another lot of the same ore was worked by the writer in the way described. 25 tons ; gold and sulphurets $3.92 per ton, tailings 83 cents ; total value of ore, $4.75 per ton. One lot of 28 tons from adjacent mine—free gold, $2.14 ; sulphurets, $4.20 ; tailings, 80 cents ; total value of ore, $7.14 per ton. Worked on one Tustin at rate of 27 tons per 24 hours, and three plain Frues, tailings sample taken from each vanner every 10 minutes. During this time the same ore gave in stamp mill, tailings from $2 to $4 per ton.

In view of the foregoing facts, there can be no reasonable doubt of the very injurious action of sliming or extension of the surface ; moreover, the experiments are in accord with other experience.

To express the matter briefly, it requires twice as much gross power to slime ore than to granulate it, and the loss of the valuable metal or mineral will be greatly increased.

The conditions necessary for perfect granulation, such that the fewest grains of small diameter will be made, are two:

The blow must be proportional to the work to be done on any grain.

The discharge of the reduced grains must be as rapid as possible.

No machine can fulfill the first condition, but all average it. The perfect machine will operate only on grains of the same diameter, or on groups in which the ratio between greatest and least diameters is constant. Thus, if the ratio be 2, the largest diameter be 40 mm. (1.6 inches). Then the groups will be 40 to 20, 20 to 10, 10 to 5, 5 to 2½, etc., at each reduction a sifting and the various sizes pass to their respective machines. Such system well carried out should reduce the slimes on hard clean ores to not more than two per cent., calling finer than 120 mesh slimes, and should in a measure approximate to the curve marked "Ideal" on Diagram 1. This would necessarily involve rollers and gradual reduction by them.

APPENDIX.

EXPLANATION OF THE DIAGRAMS.

Diagram No. 1 is constructed from the following data:

TABLE No. 1.

SHOWING THE NET SPACE BETWEEN THE WIRES OF CLOTH USED FOR BATTERY SCREENS AND SIEVES. SAN FRANCISCO, CAL.

Trade Number or Holes to the Lineal Inch.	Brass wire cloth.		Steel wire cloth. Foreign.		Steel wire cloth. Domestic.	
	m. m.	Inches.	m. m.	Inches.	m. m.	Inches.
12	1·55	0·0610	....	....	....	....
14	1·32	0·0520	....	....	....	....
16	1·25	0·0490	....	....	....	....
18	1·09	0·0430	....	....	....	....
20	0·94	0·0370	....	....	....	....
24	0.73	0·0290	0·69	0·027	0·64	0·025
30	0·55	0 0220	0·56	0·022	0·46	0·018
35	0·47	0·0190	0·49	0·019	0·38	0·015
40	0·40	0·0160	0·42	0·017	0·33	0·013
50	0·30	0·0120	0·36	0·014	0·26	0·011
60	0·25	0·0100	0·29	0·011	0·19	0·008
64	0.24	0·0090	0·28	0·011	0·18	0·007
70	0·22	0·0090	0·25	0·010	0·16	0·006
80	0·20	0·0080	0·23	0·009	0·14	0·005
90	0·18	0·0072	....	....	....	....
100	0·16	0·0061	....	....	....	....
120	0·12	0·0050	....	....	....	....
150	0·08	0·0030	....	....	....	....
160	0·06	0·0026	....	....	....	....

TABLE No. 2.

MEASUREMENT OF THE THICKNESS OF THE STANDARD NEEDLES USED FOR GAUGING HOLES IN RUSSIA IRON BATTERY SCREENS. SAN FRANCISCO. CAL.

Trade Number of Needle or Screen.	Diameter of Needle or hole in m. m. Calculated.	Diameter of Needle or hole in inches. Measured.	Nearest trade number of brass wire cloth.
No. 1	1·110	0·0436	No. 18
2	0·996	0·0392	18
3	0·950	0·0374	20
4	0·863	0·0340	20
5	0·813	0·0320	24
6	0·720	0·0284	24
7	0·662	0·0261	24
8	0·580	0·0228	30
9	0·515	0·0203	30
10	0·452	0·0178	35
11	0·391	0·0154	40
12	0·375	0·0148	40

Diagram 2 shows the pulp curves from various ores and processes. A portion of the square has been cut away to insert the description of the ores and process of reduction. These are all from early experiments and are inserted to show that the pulp curve may be either concave or convex to the origin of co-ordinates.

The curve marked "*Ideal*" is what good practice should approximate to. Thus, if the ore is crushed through a 35 mesh sieve and 90 per cent. will rest on a 50 sieve, and if this pulp having a diameter between 0.3 and 0.45 m. m. (12-1000 and 18-1000 of inch) is sufficiently small to release the enclosed mineral, then it is clear that no pulp need be finer than 50 sieve. Theoretically every grain should be of the same diameter, but as this is impossible, the percentage of small grains should be as low as possible. Therefore the ideal curve should be like the one given.

Diagram 3.

This requires no explanation other than given. The percentages were determined with more care than those of Diagram No. 2, because the conditions were very favorable for an accurate sample.

Diagram 4.

The round dots are the observed values. The size of the battery screen is a known point; also the size, x=.001 mm.=100 per cent. is a known point. The equations of the curves are found by trial, the problem being to find some curve that will pass through the initial and terminal points and conform as nearly as possible to all the observed points. When this equation is differentiated, the new equation will give the weight of all the grains for any diameter x. These curves are marked a, b. The areas inclosed by each and shown by the shading are=100 per cent., because if the equation of the curve be integrated it must make 100 per cent.; that is, all the pulp is smaller than the battery screen. It should be noticed that the equation of curve A has its origin at x=.001 any y=100, so that the y of the equation counts downward and means the quantity of pulp smaller than x diameter. This is done to avoid writing y=100—ax. Curves a, b, are plotted on a scale of one-tenth of their value. The object being to find the differential curve and the curve of surface from any pulp curve, calculus can be dispensed with

and the graphical method can be used. Draw a smooth free-hand curve and measure the value of the tangent for the various diameters, as x=.02, .04, .06, etc. Plat these values on the same diagram—the derived points will perhaps show irregularities—draw a smooth free-hand curve through all these points; this will be the differential curve. To find the surface, take values of y in this differential curve corresponding to any x, and divide it by x; with these quotients plat a new curve. This is the curve of surface; any ordinate y in this curve shows the surface for x. The area inclosed by the curve is the total surface.

Technical Society of the Pacific Coast.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

VOL. III.—MAY, 1886.

MINUTES OF MEETINGS.

REGULAR MEETING.

May 7, 1886.

President Mendell in the chair.

The minutes of preceeding meeting were read. There having been some question as to the accuracy of the record relating to the motion of Mr. Wagoner on the appointment of a committee to consider "the question of the appointment of a Board of Public Works," that gentleman stated that the Secretary had recorded his motion properly. The minutes were therefore approved.

Luther Wagoner read a paper on "The Theory of Ore Crushing."

The committee appointed at the April meeting to consider the question of "the appointment of a Board of Public Works by the Government," presented a written report.

On motion of Mr. Schuyler the Executive Committee was instructed to print the report in the Transactions.

On motion of Mr. Manson it was resolved that after publication of the report, and its receipt by members, the subject be considered at the regular meeting in June, and that notice of such proposed discussion be sent to members by the Secretary.

On motion of Mr. Wagoner the Secretary was instructed to notify the Secretary of the Civil Engineers' Committee on the appointment of a

Board of Public Works, that the Technical Society of the Pacific Coast had not yet appointed a permanent committee, but was still considering the subject.

The following is the report of the committee appointed at the April meeting of the Society :

REPORT OF THE COMMITTEE ON NATIONAL BOARD OF PUBLIC WORKS.

We, the undersigned, desire to present the following report as our views upon the question submitted for our consideration, viz.: The appointment of a Board of Public Works by the Government, and together with same is respectfully submitted the dissenting report of Capt. A. H. Payson.

LUTHER WAGONER,
MARSDEN MANSON.

REPORT.

At a meeting of the Technical Society of April 2nd, Mr. Wm. Blunt, ex-Secretary of the Executive Board of the "Temporary Civil Engineers' Committee on National Works," addressed the Technical Society, and explained the object of said committee in advocating a course of general action being taken by the engineering profession to effect a change in the present system of public works.

Our committee was appointed on a motion made to consider the desirability of our Society taking some action towards identifying itself with the movement advocated by the Engineers' Committee, at that time in session at Cleveland, Ohio.

We preface this statement to our report as warranting in our minds our treating the question submitted to our investigation in its widest sense—less as applying to the consideration of what specific measures suggest themselves at present for attaining a desired end, but rather as to whether in our opinion it be desirable for the Technical Society to take part in an already existing movement seeking to bring about an amelioration in the policy of our Government as regards its internal improvements.

As the minority report of Captain Payson presents most explicitly and ably a statement of many objections to our present system of conducting public works by annual appropriations made by Congress, in which we entirely concur, we beg to present his report, to which we will append our grounds for exception.

* * * * * * * * * * * *

REPORT OF CAPT. A. H. PAYSON.

It is hardly possible to imagine a system of appropriation for public works more fatal than the present one to their efficient conduct, and more productive of disaster and extravagance.

By this system, engineering considerations are entirely disregarded.

Appropriations are made by the contending influence of private interests, and in amounts which have no relation to the importance or cost of proposed works, but result simply from mutual concessions among

these interests, to the end that the total of an appropriation bill may not become insupportable.

Appropriations for new work are made in spite of adverse recommendation from the Chief of Engineers and his subordinates; and works begun are in subsequent years left wholly unprovided for or starved by insufficient grants of money.

It results that exact preliminary estimates are impossible, and that, with one exception, there has not been an important river and harbor work undertaken in this country during the last twenty years which has not been made extravagant in cost or jeopardized in success by the financial uncertainties of the present irrational and improper system.

The one exception is the case of the Eads' jetties, at the mouth of the Mississippi, and for these Congress made a radical departure from its usual course, and in one act made provision for the entire work.

A reform in the legislative part of a system of public works could take two directions: 1st—The creation of an officer who would probably change with the party in power, like the French Minister of Public Works, with a trained permanent engineering staff under him; who would submit his estimates to Congress to be passed, rejected, or reduced in the total by that body, without power to modify details. 2nd—A law, which could probably only be effective as an amendment to the Constitution, providing that no public work should be undertaken until a reliable estimate of its total cost was had, and an appropriation made of the full amount of this estimate, with specific provision for the necessary funds out of some part of the public revenue, or by new taxation, should the condition of the treasury make this necessary.

The first plan leads directly to Cabinet responsibility and participation in the debates of Congress, involving such radical change in our legislative system and displaying features so foreign to our methods, that its adoption may now be left out of the question.

The second plan has a precedent in the action of Congress on the Eads' bill, and seems to furnish all necessary safeguards, both for the control of work by the legislative body, and that the engineering shall not be hampered for lack of money at proper times. Experience with the pension bills plainly shows that a definite provision for the expense of any measure should be an essential feature of the act authorizing its commencement.

The great and crying evil of our present system lies in the legislative part of it; and the question arises whether the proposed transfer of control to a Board of Public works would effect improvements in this respect. There seems no reason for such a hope. The motives which underlie the present system and result in the present abuses are so powerful that it is likely the River and Harbor Bill itself will fail to pass without their support.

It is hardly to be believed that Congress will yield that control over details which now makes the passage of the bill possible, to any official or body of officials, no matter how high their professional standing, private character or personal influence.

The case or the Light House Board has been urged by one of the chief organizers of the movement our society is asked to support, as that of a body in contrast with the Engineer Bureau in organization, and whose recommendations are usually followed by Congress. The difference in organization is not essential, as in one case we have a Board with preponderating military and naval membership, acting on advice of subordinates exclusively naval and military; and in the other a military chief, acting upon reports and recommendations of military subordinates.

Though aids to navigation, when authorized, are usually put where recommended by the Board, the advice and opinions of that body are, as a matter of fact, as flagrantly disregarded by Congress in engineering matters, as those of the Chief of Engineers in the River and Harbor Bill.

The establishment of lights may be recommended over and over by the Light House Board as urgently necessary, without effecting an appropriation. Work begun at a great expense has often to be abandoned for years from failure of subsequent grants, and there are cases where estimates submitted by the Board have been actually increased in Congress.

There seems no present ground for hope of remedy for these legislative abuses in any mere change of personel in the administration, and that remedy will only come, in my opinion, after the evils of the present system have become so grave and plain to the public mind as to force the abandonment of the present indiscriminate efforts at river and harbor improvements by the General Government.

When that has been brought about, we may hope to see established some rational and settled policy of appropriations, and the limitation of disbursements from the National Treasury to works which are, beyond all question, of national importance.

Assuming that Congress will adhere to its present faulty method of appropriation, we are led to the question, whether it is desirable, under these methods, to seek a change in the administration. In considering this, we must not contrast the existing personel and organization with an ideal creation, but should inquire what change might, in all human probability, be expected from legislation in the present temper of Congress and state of the public mind on the Civil Service. To be practical, we must ask, not whether improvement is possible, but whether we are likely to get it from the influences and with the machinery which will seek and effect the change.

The control of River and Harbor work fell into the hands of the Corps of Engineers accidentally, but naturally, at the close of the civil war, and has never since, I believe, received the formal sanction of a law. The system was created by and continued in expediency, and that it has endured so long is some testimony to its merit. In the officers of the Corps, the Government had the service of men for whom, as a body, it could be claimed that by education and intelligence, they were well fitted to undertake the study of subjects of which, in this country, there was at that time practically no experience; while their life tenure of office gave guarantee, which can be had in no other way, for an honest disbursement of money. The policy of the Government was not fixed as to internal improvements, nor has it since become so, and can be abandoned or reversed, as it has already been abandoned and reversed, at any time by the action of Congress.

Under these circumstances, the selection of the Corps of Engineers for the duties imposed by the River and Harbor Bill was a natural one, and had precedent in the administration of public works in both England and France. The officers of the Royal Engineers have always been used for civil work in England and India, to the extent to which they could be spared from their military duties; and the highest graduates of the French Military School, the "Polytechnique," elect, by graduating rank, to enter various branches of the civil engineering service. Rhetoric has been used to show that military habits of thought and action are in essence distinct from civil, and that they disqualify their possessor

for the judicious conduct of civil engineering work, or business relations with the world at large.

The man who plans and orders without hearing or weighing, as Mr. Powell of the Geological Survey has alleged, is the military habit, would be probably unsuccessful in either military or civil life ; but granting the objection to military training and association to have weight, it can be shown that this objection has but a limited application to the Corps of Engineers as it now stands. Of its officers, all but the eighteen now highest in rank, have graduated during and since the war. Fortification work, which in its methods differs not at all from civil constructions, has been suspended since 1876 and for more than twenty years the officers of the Corps have found their most important work in, and directed most of their thoughts and time to the subject of River and Harbor improvements.

Whatever criticisms may be made as to the success or ability of these efforts, it can hardly be urged against a great majority of the Corps that their training and associations have been so exclusively military as to unfit them for civil life. All the experience of River and Harbor improvements, which we now have in this country, is in the Corps of Engineers and the civil assistants who have been associated with it. Large sums of money have been disbursed without scandal, while the personal independence which can only come from a life tenure, has, against strong pressure, successfully resisted that political interference with the working force, which is the bane of our public service.

It is believed that a case cannot be pointed out of the discharge or engagement by an engineer officer, for political reasons, of any employee, from the highest to the lowest grade.

Severe criticism has been made of the complicated and tedious methods followed in the care and accounting for, of public property and the disbursement of public funds. This depends on and results from laws of Congress, for which the officers of the Corps and the military spirit are in no sense responsible ; and the same inconveniences are felt in every branch of our public administration, civil and military.

The chief and officers of the Corps have always sought simplification and relaxation of these laws, on the ground that the diverse character and liability to emergency of engineering work, rendered their rigid application disadvantageous to the public service.

Mistakes of judgment have of course been made, and many deserving men attached to the Corps as civil assistants, have justly felt aggrieved that they did not share the permanence nor enjoy the orportunities for advancement of their military associates.

Under a system which in one year appropriates $12,000,000 for public improvements, and the next year nothing, expansion and contraction of the working force is necessary, and would still be necessary, no matter what the constitution of the board or bureau in charge. It is believed that the freedom from political pressure enjoyed by the military officers of the Corps, has kept this process of selection and removal free from unworthy motives ; that they have always sought to give deserving men all possible permanence in employment ; and that the same could not be expected of anybody not independent of the fluctuating policy of Congress toward river and harbor work.

The system is doubtless imperfect and has worked injustice, for which the officers of the Corps can hardly be held responsible ; but the benefits above described are substantial ones, and we should seriously inquire, before urging a change, whether that change, in the form which it will

doubtless take, will secure the same advantages, or others, which would compensate for their loss.

What will be the nature of new legislation on the subject? If we can judge by the course of Congress in the past, its feeling, and that of the public touching the creation of life officers, we shall have a Board or Bureau of Public Works, more or less permanent, and a body of assistants under it, which will vary in numbers with the requirements of the River and Harbor Bill.

How will this Board be selected? Will the men now in civil life most fitted by professional acquirements for the places, and for that reason probably already earning large rewards, leave that competition in which their success is certain, for the small salary of a public official, without the guarantee of life tenure?

Will those officers of rank and experience in the Corps of Engineers, the desirability of whose services in a new organization is admitted by all, throw up their life commissions for the feeble inducement above described? Is it not more likely that the competition for these new places will be among those who have not achieved a definite success in civil life, and who have more confidence in the political influence they may command than in their professional accomplishments?

There is, therefore, practically a certainty that a new Bureau will not have the independence which comes from life tenure, and a probability that it may not equal in aggregate experience or acquirements the present administration.

There seems no reason to suppose that a new Bureau, however constituted, will force upon Congress a fixed and rational policy of appropriations, from which it results that a large force of assistants will, as now, have to be alternately selected and removed.

With the chiefs themselves owing their appointment to, and dependent on political causes, it is hardly to be hoped that these subordinate appointments will be made for purely professional reasons.

We need not go outside of our own Government to find a department organized for purely technical and scientific work under civil administration, where the chiefs of every important office change, as a matter of course, with the politics of the dominant party, and where neither experience nor proficiency will save the oldest employé from summary dismissal for political reasons.

It may seem illogical to admit that a thing could be changed for the better, and at the same time to resist the effort for a change; but we have ample reason to fear that the gift of Congressional reform will be the Grecian wooden horse, which will conceal the inroad of fresh dangers for our much tried Civil Service.

The motives which now seek and generally accomplish the passage of the annual appropriations would become inert or hostile were the objectionable features of that legislation removed; and without a revolution in popular and Congressional feeling in the matter, of which there are yet no signs, it will be as idle to seek benefits from a change in administration as to prune and graft upon a tree which is already dying at the root."

The fact appears generally admitted that our present system is lamentably imperfect as a basis for conducting public works; by none more readily admitted than by the corps at present charged with the execution of said improvements.

While concurring in this opinion and wishing to give to it all the

weight which our concurrence can give, we dissent from two conclusions drawn by Capt. Paysòn, namely, 1st—That the present system of annual appropriations by Congress is too deeply rooted and too effectually sanctioned by custom and political expediency to be overthrown by a proper dissemination among the general public of rational views upon this subject.

We have the fullest confidence in the intelligence of the people when a matter affecting their common interests is properly impressed upon their minds; that if this matter be but properly presented and discussed, their representatives can be relied upon to carry out their wishes.

2nd—That the formation of a permanent branch of the Civil Service, under which life tenure will be assured, is incompatible with our present political system.

That this view is erroneous, we have evidence of in the tenure of office enjoyed in the Judiciary and Coast Survey Departments, not to mention the permanent organization of the army and navy.

In our judgment, as regards public matters, the fiat has gone forth in favor of civil service reform; its future will be progressive, for the reason that the people demand business methods in public business.

In discussing this general question, the prime evil stands boldly forth in the shape of the method of obtaining and distributing the appropriations, not in their disbursement and application. The eradication of this and the substitution of a rational system, is the question to which our voices and votes as citizens and our professional discussions as members of the Technical Society should be turned.

No Board of Public Works, however competent, faithful and efficient, could accomplish good results under the present system of appropriations, nor is there any reason to suppose that a Board could obtain better results than are at present secured by the Corps of Engineers.

With the correction of the fundamental evil, the formation of a Board of Public Works will naturally follow, and must draw into its membership those men best fitted to marshal the forces of nature for Man's benefit, whether their early training be civil or military.

To conclude, in our opinion it is expedient for our Society to identify itself with the action proposed by the "Engineers' Committee," in so far as it may relate to the production of a healthy state of public sentiment in the matter of a policy of Public Improvements. Further than this, we have at present no recommendation, preferring to leave the matter open for future discussion and action, as our knowledge of the question and its issues may extend.

May 7th, 1886.

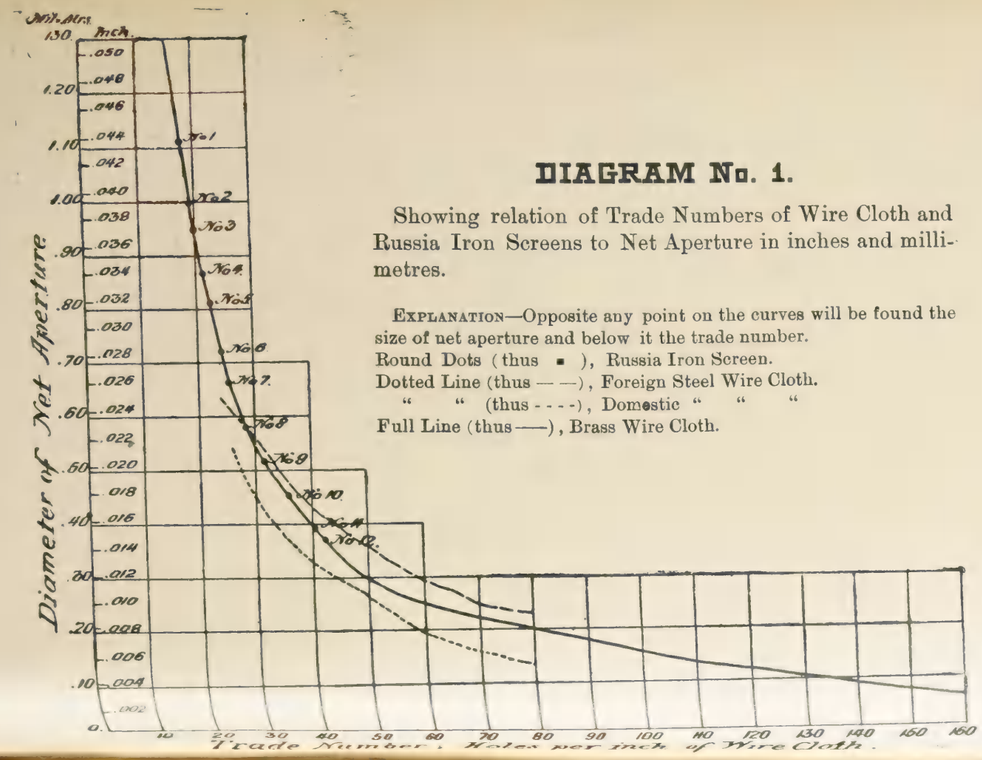
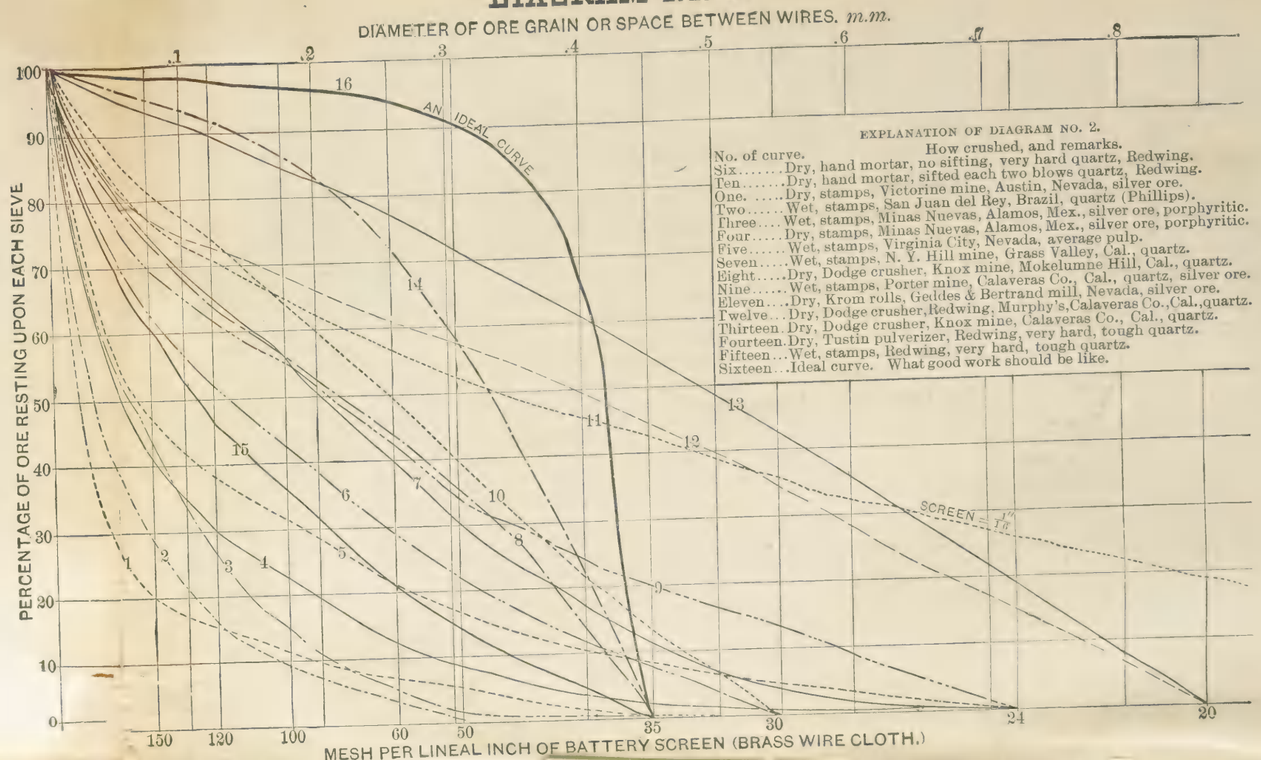


DIAGRAM No. 1.

Showing relation of Trade Numbers of Wire Cloth and Russia Iron Screens to Net Aperture in inches and millimetres.

EXPLANATION—Opposite any point on the curves will be found the size of net aperture and below it the trade number.
Round Dots (thus ▪), Russia Iron Screen.
Dotted Line (thus — —), Foreign Steel Wire Cloth.
" " (thus - - - -), Domestic " " "
Full Line (thus ——), Brass Wire Cloth.

DIAGRAM No. 2.



EXPLANATION OF DIAGRAM NO. 2.

No. of curve.	How crushed, and remarks.
Six	Dry, hand mortar, no sifting, very hard quartz, Redwing.
Ten	Dry, hand mortar, sifted each two blows quartz, Redwing.
One	Dry, stamps, Victorine mine, Austin, Nevada, silver ore.
Two	Wet, stamps, San Juan del Rey, Brazil, quartz (Phillips).
Three	Wet, stamps, Minas Nuevas, Alamos, Mex., silver ore, porphyritic.
Four	Dry, stamps, Minas Nuevas, Alamos, Mex., silver ore, porphyritic.
Five	Wet, stamps, Virginia City, Nevada, average pulp.
Seven	Wet, stamps, N. Y. Hill mine, Grass Valley, Cal., quartz.
Eight	Dry, Dodge crusher, Knox mine, Mokelumne Hill, Cal., quartz.
Nine	Wet, stamps, Porter mine, Calaveras Co., Cal., quartz, silver ore.
Eleven	Dry, Krom rolls, Geddes & Bertrand mill, Nevada, silver ore.
Twelve	Dry, Dodge crusher, Redwing, Murphy's, Calaveras Co., Cal., quartz.
Thirteen	Dry, Dodge crusher, Knox mine, Calaveras Co., Cal., quartz.
Fourteen	Dry, Tustin pulverizer, Redwing, very hard, tough quartz.
Fifteen	Wet, stamps, Redwing, very hard, tough quartz.
Sixteen	Ideal curve. What good work should be like.

PULP DIAGRAM

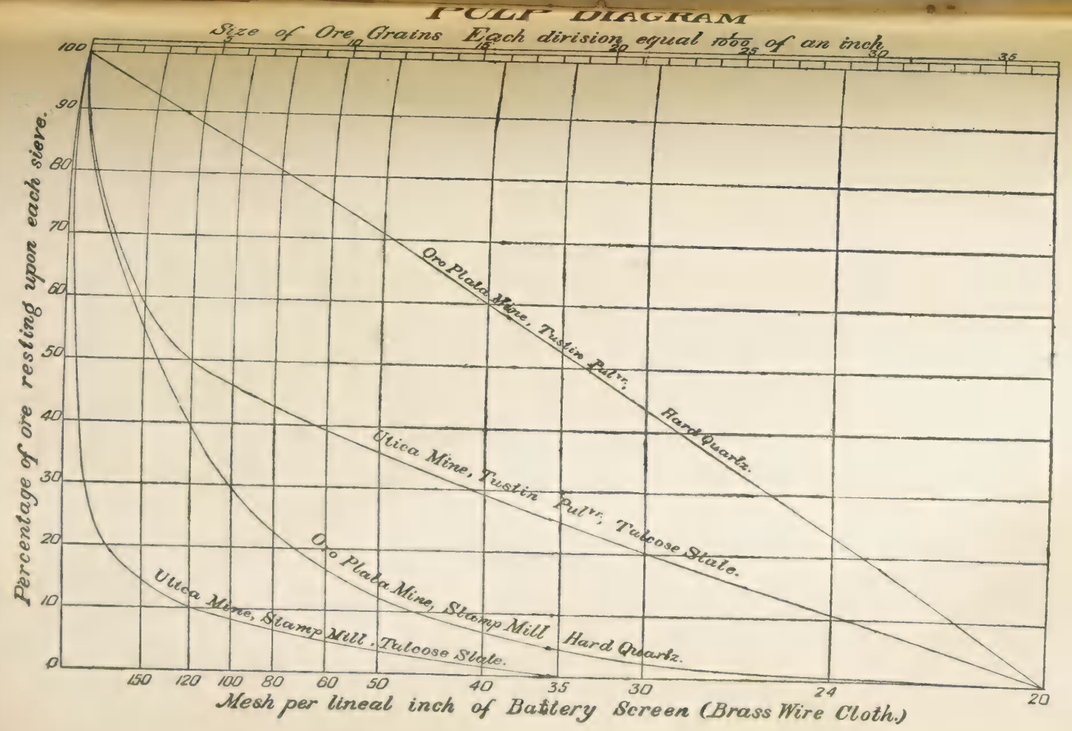
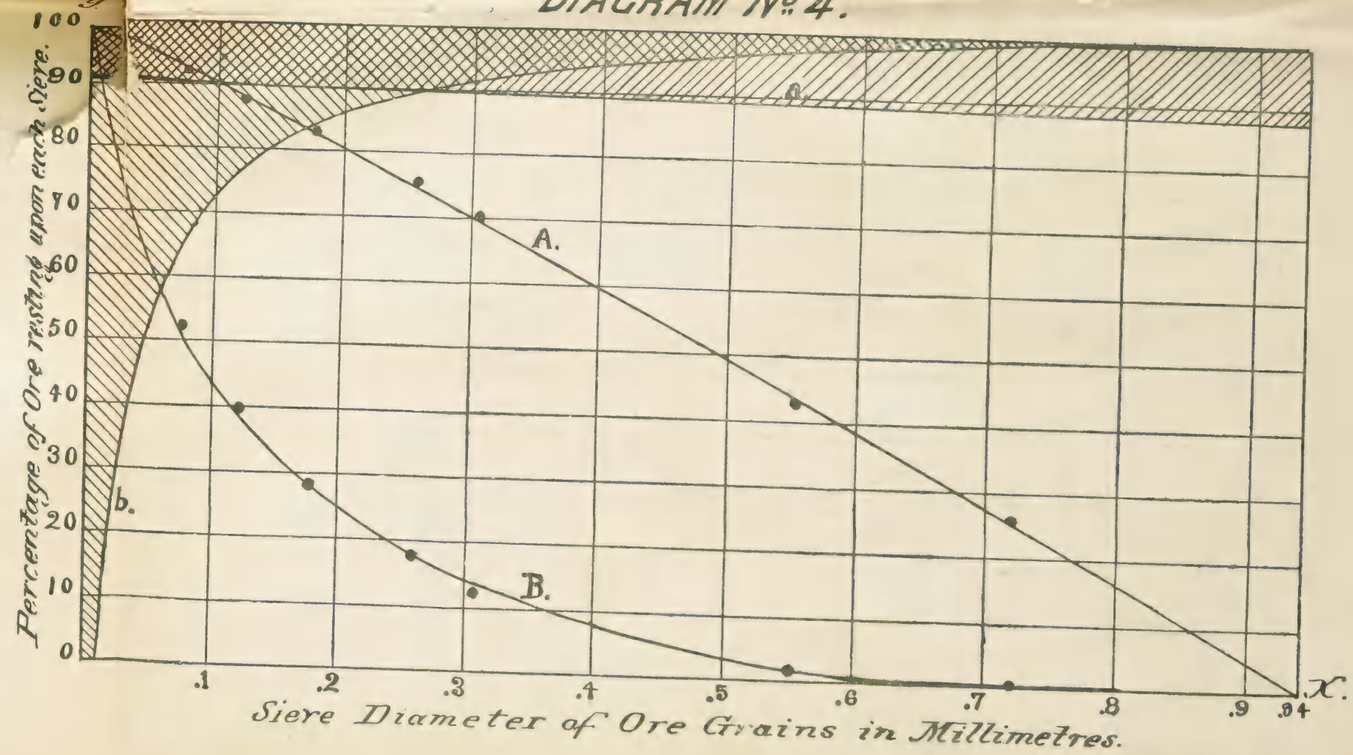


DIAGRAM No. 4.



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME III.—JUNE, JULY, AUG., SEPT. AND OCT., 1886.)

AIR BRAKE TESTS.

By W. W. HANSCOM, Mem. Tech. Soc.

Read September 3, 1886.

The object of this paper is to give some general information about the recent trials of the automatic brakes at Burlington, Iowa, with particular reference to those brakes operated by air pressure. These trials were inaugurated for the purpose of inducing owners of automatic brakes adapted to freight car service to present and test them, so that the Car-Builders Association of the United States might indorse or recommend those which proved the most economical and desirable for freight service. There were five competitors in these trials, including the Westinghouse, Eames, Widdifield & Button, the Rote and the American. The last three mentioned are termed buffer or draw-head brakes, on account of their being put in action through a compression of the draw-bar of the car to which they are attached, in contradistinction to the Westinghouse and Eames brakes, which are operated by air pressure. The Westinghouse brake uses a pressure of 60 to 80 pounds above the atmosphere. The Eames brake uses 4 or 5 pounds pressure less than the atmosphere, and is called a vacuum brake. A general description of the important features of these several air brakes,

whose actions are somewhat similar, will be sufficient. Your attention will now be called to this subject.

In the Westinghouse brake the apparatus consists of an air pump or compressor on the locomotive, a main reservoir for storing the compressed air ready for use, and an engineer's brake-valve connected to this reservoir. From this brake-valve extends a pipe throughout the length of the train, composed of iron, under each car, and of rubber hose with suitable couplings between each 2 cars, thus making practically a continuous pipe the whole length of a train. Under each car and connected to the train pipe, through a peculiar piece of mechanism called a triple valve, is a small auxiliary reservoir which is of sufficient capacity to supply air to a brake cylinder close by. This brake cylinder consists of a common cylinder with piston and rod, the rod being attached to the brake levers of the car, so that when the piston is pushed out by the pressure of air behind it the brake shoes are pressed against the wheels and the speed of the train retarded or stopped entirely, as the case may be. This triple valve consists principally of a piston and a slide valve, and when the air pressure is in excess on one side of the piston, it is pushed up and communication is direct between the train pipe and the auxiliary reservoir. This continues so long as the pressure is equal on both sides of the piston, but, if a sudden reduction of pressure is made behind this piston, leaving an excess on the other side, the piston will immediately move back, carrying with it the slide valve above mentioned. This slide valve opens communication between the auxiliary reservoir and the brake cylinder, while at the same time or a little before, it closes communication between the train pipe and auxiliary reservoir.

The operation in action or when a train is in motion, is as follows: The main reservoir is charged with air of 85 pounds pressure and the train pipe and auxiliary reservoirs are filled with air at a pressure of 65 to 70 pounds, an excess of about 20 pounds being kept in the main reservoir as a reserve for operating the triple valve. When it is desired to slow the train or stop, the engineer, by means of the brake valve, lets some of the air out of the train pipe, suddenly reducing the pressure in that

and behind the pistons in the triple valves. These pistons, moving backward, close the communication between the train pipe and the auxiliary reservoir, so that no air escapes back from that to the train pipe when the pressure is reduced. At the same time communication is opened between the auxiliary reservoir and the brake-cylinder, the compressed air in the former expands into the latter, the final pressure on the piston of the brake-cylinder being inversely in proportion to the movement of the piston or increase of volume of air. The volume of the auxiliary reservoir is proportional to the brake-cylinder, so that with an initial pressure of 70 pounds in the reservoir and a movement of 4 inches of the piston in brake-cylinder there will be a final pressure of 61 pounds; with a piston travel of 9 inches, 50 to 53 pounds; and with a piston travel of 12 inches, a final pressure of 44 pounds, provided that everything is in perfect condition and no leakages. In actual practice at the brake-trials or with the initial pressure of 67 pounds the final pressure with 6 inches travel of piston was 43 pounds. It was stated above that if a sudden reduction of pressure were made in the train pipe the piston of the triple valve would be moved. When the piston of the triple valve is pushed up by the excess of pressure in the train pipe it passes a leakage groove in its cylinder, which allows the air to pass through and into the auxiliary reservoir to charge it; and if a gradual reduction of the air pressure is made in the train pipe the excess of air on the other side of the piston and in the auxiliary reservoir will pass back through this leakage groove into the train pipe without moving the triple valve, and consequently no air will pass into the brake cylinder to operate the brakes, and the brakes will not be applied although all the air may be drawn gradually from the auxiliary reservoir.

In the Eames brake a single line of pipe is maintained throughout the train and auxiliary reservoirs and brake cylinders or diaphragms, as in the Westinghouse; but, as only the pressure of the atmosphere is used, it requires a vacuum to be maintained in the train pipe and auxiliary reservoirs as in the Westinghouse is required a pressure. An automatic valve is used on the Eames similar in its functions to the triple valve of the West-

inghouse, that is, it opens communication between the auxiliary reservoirs and the diaphragms by an increase of pressure in the train pipe, creating a partial vacuum in the brake-cylinders or diaphragms.

The pistons of these vacuum brakes are composed of rubber sheets, to avoid the leakage and friction of pistons.

It was intended in these tests to determine how far or on how many cars comprising a freight train the action of the brakes under trial would reach effectively, as without the assistance of brakemen this would limit the length of train to be properly controlled by power brakes under daily conditions. The track upon which the tests were made was about 8 miles in length, between Burlington and Middletown, part of this track being nearly level and a part having a grade of 52.8 feet per mile. The trains were to have stops made on the level from speeds of 20 and 40 miles per hour, and also at the same speeds on the grade. The trains were started from Middletown on the level, when stop No. 1 was made from a speed of 20 miles per hour; stop No. 2 on the level from a speed of 40 miles per hour; then, continuing on the grade, stop No. 3 was made from a speed of 20 miles per hour, and stop No. 4 from a speed of 40 miles per hour. The distances between all the stop posts was ample for getting up the speed desired. The speed varied some from what had been laid down, from the difficulty of reaching that exact speed at the moment of the application of the brake opposite the post set beside the track for this purpose.

The speeds at stop No. 1 on the level reached from 19 to 26 miles, and at stop No. 2 on the level from 30 to 43½ miles; at stop No. 3 on the grade from 20 to 26, and at stop No. 4 on the grade from 31 to 45½ miles per hour.

The distances run in making these stops were: In stop No. 1, from 330 to 1,302 feet; in stop No. 2, from 922 to 2,554 feet; in stop No. 3, from 320 to 2,077 feet; and in stop No. 4, from 1,077 to 3,684 feet.

The time in stopping was: In stop No. 1, from 13 to 48¼ seconds; in stop No. 2, from 22¼ to 59¼ seconds; in stop No. 3, from 15¼ to 76½ seconds; and in stop No. 4, from 24½ to 102 seconds.

These differences in speeds, distances run in stopping and time in making stops were due to a variety of causes, which it would be impossible to explain fully in the short time in which your attention is invited.

There were four kinds of trains made up for the tests—all of them having an engine, a dynamometer car next the engine, an autographic car in the center of the train, and a way car at the rear end.

The first train was composed of the above, with 24 box cars, 12 of them being loaded with 20 tons each of old car wheels, and 9 of the 12 loaded cars were placed in the rear half of the train.

The second kind of train consisted of the engine, dynamometer car, autographic car, way car and 49 box cars unloaded.

The third kind of train consisted of the above, with 24 cars loaded with 20 tons of old car wheels in each, 18 of these loaded cars being in the rear half of the train.

The fourth, same as the above, with the other 25 cars loaded with 20 tons each, same as the others, making a maximum weight of train of about 1,670 tons, with a total length of about 1,900 feet.

Each train of each competitor was required to run over the distance three times, making four stops each run.

In addition to this, the trains of 25 cars, with one-half loaded (and called mixed trains), were to be taken on the level, and at stops Nos. 1 and 2, instead of applying the brakes by the engineer, the train was to be broken in two, so that the brakes might apply themselves automatically.

Also, the trains consisting of 50 cars (mixed trains), being one-half loaded, were started down the grade at a speed of 20 miles per hour, and were required to reduce that speed to 15 miles, which was to be maintained the rest of the way down the grade, about two miles. In these latter tests the speed at starting varied from 18 to 20¾ miles, and varied all the way from these to 9 in running until the post was reached, at which a signal was given to stop, and the brakes were applied with the full remaining force.

During the early part of the trials the brakes were applied as quickly as possible by the engineer, and the trains brought to

rest in such short distances that the way car at the rear end of the train was subjected to shocks that were destructive to the car and dangerous to the occupants. After several of these sudden stops, which were called emergency stops, it was decided that the future stops should be made in as short a distance as consistent with smoothness, or to such a degree that the shocks would not be injurious to cattle or other live stock if carried on such a train. These were called service stops, although not strictly so, as in regular practice a definite point is decided upon at which the train must be brought to rest at a station; while in these, the train, after the brakes were applied, was allowed to seek its own stopping-place.

This would involve a somewhat different application of the brakes, as in one case the brakes, after being once applied, remain on continuously, while in ordinary practice the brakes are often released and applied again more than once in making a stop, especially when stopping for coal or water. This difference was more prominently demonstrated in the test of retarding the train from 20 miles per hour when going down grade, especially in the Westinghouse brake.

It may be stated that the dynamometer car at the front of the train contained an instrument carrying a roll of paper moving across the car, so geared to the axle that a movement of two feet of the paper corresponded to a movement of the train of one mile. Above, and in contact with the paper, were five pens. One was connected by levers to a spring attached to the drawbar, the movement of the pen being at right angles to the movement of the paper, and so graduated that a movement of one inch either side of a datum line indicated a thrust or tension of 6,000 pounds. The second pen made the datum line in the center of the paper. The third pen was attached to the armature of a magnet, and, by wires attached to a clock in the car, was caused to move sidewise from its path each five seconds; and thus, by a scale, the speed could be measured between any two of these marks. The fourth pen was also attached to a magnet, and a wire was run to the side of the car and to a button, so that an operator, watching the mile-posts as they passed, could, by touching the button, make a sidewise movement of the pen sim-

ilar to the five seconds marks. A wire was also run from this magnet to the engine, so that an observer, standing beside the engineer, could, by touching a button, indicate on the paper the moment when the brakes were applied. The fifth pen was also attached to a magnet, and was operated by pins on a gear-wheel driven from the axle, the pen being moved sidewise once every 16 feet of movement of the train.

In the autographic car, which was always in the center of the train, was an instrument having a roll of paper moved by gearing connected to the axle of the car, but moving a much less distance per mile of movement of the train than in the dynamometer car.

Attached to one of the brake levers under the car was a rod carrying a pencil, which had a movement at right angles with the paper, its movement being reduced so that the pressure on the brake lever could be recorded similar to the thrust on the draw-bar at the dynamometer car. This indicated the pressure, as before stated, on the brake beam on the center of the train, and the length of time or the proportion of distance which the brake was applied, during or when making the stop.

At the rear end of the train, on the rear end of the car in front of the way car, were placed three gauges, one indicating the pressure or vacuum in the train pipe, one the pressure or vacuum in the auxiliary reservoir, and the third indicating the pressure or vacuum in the brake cylinder or diaphragm. These gauges were placed on the rear end of the rear car, so that they could be seen by an observer at the front end of the way car through a window provided for that purpose.

The diagrams recorded in the autographic car were some of the most important of all taken, as these show the actual amount of force exerted against the break beam at the center of the train; and assuming that the brake beam at the car on the front of the train received the maximum amount of force, then any decrease from that as shown on the middle car would indicate the probable continuous reduction throughout the whole length of the train, and a reasonable conclusion might be formed as to the amount of brake beam force exerted at the last car. This information is of consequence, as showing on how many cars the

brakes under trial could act effectively, or, in other words, the length of a train would be limited, so far as these brakes were concerned, to the number of cars on which they would act effectively, and yet be in such a condition that the brakes under the whole length of the train would be applied in case the train should break in two. These brakes may be applied throughout the length of any train so long as a sudden reduction of pressure to the extent of about 3 pounds can be obtained; and when the length of the train pipe reaches a point when the sudden is changed to a gradual reduction, then the triple valve ceases to be acted upon and the brake at that point is of no use.

In the train pipe of the Westinghouse brake an average pressure of 65 pounds was carried; and when this was reduced to nothing suddenly at the engine, the triple valves nearest that point would be acted upon the quickest, giving the greatest movement and largest opening or communication between the auxiliary reservoir and brake-cylinder; but as the distance from the engine increased, the suddenness of the release would decrease until a point, as before stated, would be reached, when the reduction of pressure would be so gradual that the triple valves would cease to be acted upon, and beyond which no brakes would be applied.

It has been before stated that when the brakes were applied with full force, that is, the release of the air in the train pipe was as rapid as practicable, the stop was so sudden that it was destructive to the strongest cars on trial, and that, in consequence, it was decided to make the stops in such time and distance that the shocks would not be injurious to live stock, or that fragile goods be damaged. To accomplish this necessitated a partial application of the brakes, and therefore required a less sudden release of air from the train pipes. About the least sudden reduction of pressure required to operate the triple valves is about 3 pounds; so, in order to set the brakes on the last or rear car of a train, the sudden reduction of train pipe pressure at that point must be 3 pounds, and this will move the triple valve so as to partially open communication between the auxiliary reservoir and brake-cylinder, and make a partial application of the brakes. Understanding this, we must conclude that

in any length of train, with the brakes under trial, the brakes will be applied with greater force at the front of the train; and if all the triple valves move equally free, there will be a gradual reduction of brake-shoe pressure, from the front to the rear, depending somewhat upon the time in making the stop as to the proportionate distance in which the rear brakes are acting.

It seems plain, therefore, in making stops in regular service where the application of the brakes must be necessarily light, the reduction of train pipe pressure at the engine will be so small that the sudden diminution of pressure will pass into gradual, not far away; and at any point where this is the case and the triple valve ceases to act, the excess of pressure in the auxiliary reservoir must return again into the train pipe and be wasted; and not only this, but, to still further graduate the reducing pressure in the train pipe.

That these conclusions must be correct will be seen, when it is known that in making an emergency stop with a train of 50 cars, and a speed of 20½ miles on a level, the distance run in making the stops was 354 feet, and the time 54 seconds, and that the average effective force on the brake lever at the center was only about 2 per cent of the maximum required to equal the weight of the car.

The diagrams taken show that the pressure on the brake beam at the center of the car only commenced to be applied during the last one-eighth of the distance run in making the stop. As the speed increased, and the time and distance also, the diagrams show the same characteristic features. In a stop with the same train of 50 cars, with a speed of 43 miles per hour, the distance run in making the stop was 1104 feet and the time 43 seconds. The diagram shows that the pressure commenced to act on the brake beam when 20 per cent. of the distance had been passed over and that the average pressure was about 20 per cent. of the maximum required to equal the weight of the car.

These were emergency stops, where the brakes were applied full force.

In a service stop on a level, with speed of 20½ miles per hour, the distance in stopping was 608 feet and time 26 seconds. The diagram shows that the pressure was being applied during 23

per cent. of the distance, and that the maximum pressure reached was 21 per cent., and the mean pressure a little more than 2 per cent. of the maximum required to equal the weight of the car. In a stop with speed at 41 miles per hour, the distance run was 1,787 feet in making the stop, and the pressure was being applied during 63 per cent. of the distance, the maximum pressure being 53 per cent. and the mean 20 per cent. of the maximum required to equal the weight of the car.

In the test with a train of 50 cars going down grade, where the speed was to be reduced from 20 to 15 miles, where a gentle application of the brake was required, the sudden reductions were about three pounds on the engine. It is not known just how far along the train the brakes were applied, as no pressure was indicated on the diagram paper in the center car, so that more than one-half the brakes were not acting. That the pressure was being gradually reduced in the train pipe and auxiliary reservoirs was shown by the gauges on the rear car, which showed a diminution of pressure from 62 to 37 pounds, the pressure in the auxiliary reservoir diminishing with the pressure in the train pipe. This action shows that the shorter the train pipe the more prompt will action of the triple valves be, and that by reducing the length of the train pipe, or by simply cutting out some of the rear brakes, in long trains one-half, a more effective action will be had of the remaining brakes in communication with the engine. As the cutting out of the rear brakes makes them valueless in case of the train breaking in two, it would be the safer plan to allow all the brakes to be connected, although at the sacrifice of efficiency and large waste of air from its returning back from the auxiliary reservoirs into the train pipe when making service stops in regular work.

In addition to this the work on the brake shoes and wheels is unequally distributed, and there is a corresponding liability of excessive pressure on the wheels of the cars next the engine, causing them to slide and making them flat in spots.

These tests show the necessity of making some improvement in the brakes under trial, so that the brakes throughout a train may be applied with a gradual reduction of pressure in the train pipe, as the results seem to point to an impossibility of applying

these brakes gradually or with an equal pressure on each brake beam, when the admission of air to the brake-cylinder depends upon a sudden reduction of air in the train pipe.

Although this paper has already been extended much beyond the writer's original intention, yet but one feature of these most elaborate and interesting brake trials at Burlington has been partially touched. The many points of important information will no doubt be thoroughly discussed by the railroad community in particular and the engineering profession in general when the Committee from the Car Builders' Association shall have completed their labors and made their report on these tests of unparalleled magnitude.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME III—JUNE, JULY, AUG., SEPT. AND OCT., 1886.)

MINUTES OF MEETINGS.

REGULAR MEETING.

June 4, 1886.

Mr. Dickie in the chair.

The Chairman announced that the discussion on the subject of "The Appointment of a Board of Public Works by the Government."

Mr. Wagoner moved that the matter be postponed for one month, in view of the small attendance at the meeting. Mr. Wagoner withdrew his motion.

Mr. Blunt was invited to speak, and stated that the purpose of the Central Committee is to obtain the appointment of a Board of Public Works, but the appointment of committees by different societies does not commit the said societies to any definite course. The object is at present to agitate the question.

Remarks were made by Mr. Wagoner, Mr. Vischer, and the chair.

The Secretary read a printed address from the Executive Board of the Council of Engineering Societies.

The Secretary was instructed to communicate with the Secretary of the Council in regard to the question.

REGULAR MEETING.

July 2, 1886.

The meeting was informal, not being called to order, and the minutes not being read.

Mr. Gardner F. Williams gave a verbal description of the gold fields and diamond mines of South Africa, with the methods of working, and exhibiting specimens from the mines.

REGULAR MEETING.

August 6, 1886.

In the absence of the President Mr. Bowie was called to the chair.

Mr. Gutzkow described verbally an apparatus for determining the loss of quicksilver in working quicksilver ores. A discussion ensued on the subject of condensation of mercurial fumes.

A letter was received from John Eisenmann, Secretary of the Executive Board of Council of Engineering Societies on National Public Works, in answer to questions sent by the Technical Society. On motion the letter was referred to the Committee on Board of Public Works.

REGULAR MEETING.

September 3, 1886.

In the absence of the President and Vice-President Mr. E. J. Molera was called to the chair.

Hans C. Behr acted as Secretary *pro tem.*

W. W. Hanscom read a paper entitled "Air Brake Tests," giving an account of the recent trials of automatic brakes at Burlington, Iowa. He stated that the full reports of the trials would be published in about a year. A short discussion ensued as to the cause of the loss of pressure described by Mr. Hanscom.

Mr. Bowie read a letter from the President and Secretary of the Executive Committee of the Council of Engineering Societies on National Public Works, asking the views of the Society.

Mr. Manson, of the committee appointed by the Technical Society, made a statement as to the status of the matter.

On motion of Mr. Bowie seconded by Mr. Percy, it was decided to discuss the question at the next meeting.

Mr. Manson thought the members should make it a point to be present at the October meeting, and discuss the question of joining in the movement referred to.

REGULAR MEETING.

October 2, 1886.

A quorum not being present, the meeting was not called to order, and no business was transacted.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME III—NOVEMBER, 1886.)

THE HIGH PRESSURE HYDRAULIC SYSTEM OF DISTRIBUTING POWER IN CITIES, WITH SOME REMARKS ON OTHER METHODS.

BY J. RICHARDS, MEM. TECH. SOC.

Read November 5, 1886.

GENERAL REMARKS.

The distribution of motive power in cities has for many years past been considered in a vague kind of way. Centralization, it was well known, had great advantages over a diffusion of small motors, and the principle, to so call it, that laid at the bottom has had general recognition and acceptance, and had the subject been earlier treated in a plain matter-of-fact sort of way, there is no doubt that it would now have a wide application.

Instead of this, the subject has, until very recently, been looked upon as one embodying new and untried inventions and as a system that had to be discovered in all of its essential features. The novelty of application was mistaken for a novelty of means, and this idea was promoted by those who had patents or plans for special methods.

The Steam Power Company of New York is an illustration.

This company, one of the only ones for distributing power that has failed, was based upon the inventions and plans of one man, and he, instead of employing ordinary well known means and calling in the counsel and assistance of competent men and mechanics, proceeded on the assumption of having discovered new and better methods and that the system called for something different from common and well proved practice.

The first company failed, as we all know, losing a large investment; so also various other companies organized on the same method, and while this failure of the "Holly system," as it was called, has to a great extent deterred the American people from entering upon power distribution, there has been something done and with uniform success I believe, except in the case named.

During five years past, power distribution has fallen into different hands. Practical business men and engineers of known ability have taken it up, and it has been removed from the field of speculation and discovery to become a sober and important fact among useful industries.

Steam as an agent of transmission has been abandoned, except under certain conditions to be hereafter noticed, but the principle of distribution was not dependent on steam, except where heat as well as power was required. Other and better means have been adopted, and as before said, a different class of people have taken up the matter.

It will be quite impossible to include notice or even mention here of all the various schemes in progress or in use at the present time, nor is it necessary, the purpose being merely to offer some explanation and comments on the high pressure hydraulic system, with such notice of other methods as will be required for comparison.

In 1868, the writer published in the *Journal of the Franklin Institute*, Philadelphia, an article on the "*Centralization of Motive Power*," which, so far as he knows, was one of the first wherein the broad idea of power distribution was suggested. Since that time, he has watched the subject continually, and noted with interest the progress made in that direction. That was but a short time ago, but long enough to precede many wonderful discoveries and additions to science and art that have

a bearing on the matter. Electricity and natural gas, and also the distribution of manufactured gas as fuel, may be named. In hydraulics and pneumatics also there have been many and important changes, all tending to render power distribution more inevitable.

In London and Hull, in England, and in Portland, Oregon, this country, have been erected works for generating and distributing power by hydraulic means, and in Paris, France, and Birmingham, England, works have been erected for similar purposes, operating with air as the transmitting medium. Some of the principal facts connected with these enterprises will be given in a future place.

METHODS OF DISTRIBUTING POWER.

The different methods now in use for distributing power are steam, compressed air—water—and direct gearing, such as ropes, bands, shafts and links. To these must soon be added, if not now, electricity and combustible gas.

Each of these systems are different in their nature, and have special adaptations to various objects, which will be only briefly noticed here, the purpose being to consider them only so far as transmitting power to drive manufacturing and hoisting machinery in cities—the first and main object of all systems of the kind.

Steam transmission is one of power and heat. Air one of power, ventilation, and, to some extent, temperature. Electricity one of power and light; while gas comprises power, heat and light. The hydraulic system is confined to power transmission alone.

Steam.—In respect to steam transmission, its merits and adaptation to general purposes can be summed up in the remark that if it were a suitable means for general distribution it would long ago have come into use. Its conveyance requires only simple pipes, such as any engineer will contrive. It is always conveyed a longer or shorter distance from the place of generation, and there is continued effort going on to extend this distance; so we may fairly conclude, as before said, that the commercial, if not the practical limit, has been reached.

The difficulties to be met with in steam distribution are easy to discern. It is essentially a system of heat distribution, and heat is too subtle an element to be confined and conveyed in pipes. It escapes through walls of metal more readily than through a stratum of air of equal thickness, and its expansive power is gone, for ordinary working purposes, at a temperature of 280 degrees or at 50 lbs. of pressure. Condensation is continually going on, and in such apparatus for conveyance as is generally provided, amounts, in long distances, to more than the energy transmitted. There is in this city one case of transmission for a distance of 400 feet only, where the liquefaction is double the work—that is, two-thirds are lost; the pipes are underground, and are repaired at least six times each year.

I am well aware of the very economical transmission of steam sometimes attained, or reported at least, but it is almost useless to consider the method outside of such means as ordinary practice provides.

There is also the objection of danger inseparable from the confinement at high tension of an elastic gas with a temperature of 300 degrees. A fact that had unfortunate demonstration in New York, where the interdiction of the system was mainly on the grounds of danger from explosion.

There are besides other impediments, such as the expansion and contraction of pipes, the high temperature at motors, and the skill required in their care.

Some years ago, when acting as engineer for a power-distributing company in this city, where we had about 1,000 feet of distributing pipes, and supplied steam to five or six consumers, I carefully observed all the facts, economical and mechanical, and after two years' of such observation, reported against the expediency of extension. I devised means of equalizing and controlling pressure and detecting waste, also for measuring the amount of steam consumed, but found such apparatus could not be maintained in such a limited case, where there was wanting a system of inspection and control. I have no confidence in the system beyond such distances as are continually in view and control, and where the areas exposed to radiation are too limited to cause serious loss.

Air transmission.—Air, as a means of transmitting power, has had wide application in various countries during twenty years past, so the capabilities, merits and faults of the method are now very well understood. The loss by transmission, or, by compression and expansion, is from 45 to 55 per cent., and this on ecomonic grounds, places the system at great disadvantage.

When air is suddenly compressed, the tension of the reduced volume is due in part to the mechanical force applied, and partly to heat, the smaller volume containing nearly the same amount of heat the greater one did. It is therefore evident that so much of the tension or pressure as is due to heat, had to be overcome by the compressing power; and as this heat soon passes off by radiation the force it represented is lost.

The same thing occurs in lowering the pressure, or in giving off power. The temperature of the air falls by expansion, and its effective volume is reduced accordingly, so the loss is, as before stated, leaving only 45 per cent. or so for working effect. This loss can be, and is, to a great extent avoided, by cooling the air during compression by well-known methods, but in the best examples that can be referred to, as at Mont Cenis; also the Birmingham and Paris companies, hereafter to be referred to, the power utilized is much as before stated.

There are other impediments, such as freezing at the point of discharge when the pressure is high, the difficulty of detecting leaks and waste without color or odor to indicate them, and the want of lubricating properties in piston motors or other machines for giving off power.

These things have not however deterred engineers and investors from projecting and laying down extensive plants in Paris, France, and at Birmingham, England. These plants are on very different methods, but in both cases have been carefully considered, and there have been included in the estimates, all losses that are computable.

The company at Birmingham proposes to employ a positive pressure of 50 to 60 lbs. above the atmosphere, and to substitute air for steam in the case of hundreds of small steam engines scattered throughout the denser part of this great manufacturing city.

The loss of 50 per cent. or so in transmission from the main engines will be mainly, perhaps wholly, compensated by the waste unavoidable from generating steam in numerous small steam boilers, their deterioration in value, and in risk, while an ample margin for profit will, it is supposed, be found in the room saved, reduced insurance rates, the expense of firing, and the greater steadiness and constancy of the centralized power. Provision has been made for 10,000 H.P.

The system in Paris is altogether different. A negative pressure or partial vacuum of from 10 to 12 pounds is employed, the air flowing inward to the central station. The reasons for adopting this method are, as in the case of Birmingham, to be found in peculiar local conditions of use. They are not in any sense rival methods for the same purpose.

Any one well acquainted in Paris knows there are thousands of small shops in nearly all parts of the city where power is required, generally only a small amount, and commonly supplied by hand machinery. The power is required by jewellers, hatters, wood and ivory-turners, cloth-workers, machinists, and so on; generally from one-fourth to one horse power in each case.

The company propose to supply this want by pneumatic engines of simple construction, which are rented with the power and air, and are included in the charges made. The charge is about 50 cents an hour for each horse power, which seems very high when compared with rates here for larger amounts of power generated by steam engines; but when only one-fourth of a horse power is employed, $1.25 per diem seems reasonable enough for Paris.

These rates will no doubt be much reduced, because the first ten months' run showed a profit of 100 per cent., exclusive of interest and deterioration. The first power sent out, or "brought in," rather, was in June of last year. In April last the company had 72 subscribers, and had received 240 applications for power.

I may mention that the negative system is adopted to prevent sending questionable air into close rooms, the low pressure to avoid freezing, to better guard against leaks, and perhaps other reasons I am not acquainted with.

Mechanical Transmission.—In this term is included ropes, bands, shafts, links, and so on, all familiar expedients, to which may be applied the same rule as in the case of steam, namely, not involving new discovery, they have no doubt reached the limits of profitable application.

For a time wire rope transmission gave promise of conveyance at long distances, but careful observation at Schaffhausen, on the Upper Rhine, in Germany, and at the falls of the Rhone, in France, has furnished all required data for determining limits for the system. Room, expansion and contraction, abrasive wear, numerous lubricated bearings, air friction soon balance the comparative saving.

The writer was impressed with what may be called the link system, seen at the Isle of Man, during a recent visit there. The power from the celebrated Laxa water-wheel is conveyed a thousand feet or more horizontally before descending the mines by links, or pump-rods they might be called, having a stroke of 20 feet or more, the ends or joints being carried on trucks running on T rails apparently with a minimum of friction. It has of course no more than the old pump-rod system except as to its horizontal position and being above ground.

I am of the opinion that among the various means of mechanical transmission, shafts properly arranged can claim the first place. With the present methods of lubrication, pivoted bearings, and clamping connections, steel shafts of small diameter and driven at a high speed, especially when laid under ground, can be extended for long distances with but little loss of power or risk of detention. Torsion, and consequent irregularity of motion of course fix a limit for shafts, and I am not speaking of them as a method of general transmission, but in comparison with ropes, bands and steam pipes.

Gas Transmission.—It is only very recently that combustible gas could have been considered among means for power-transmission. The idea, for it is little more at this time, has grown out of the natural-gas system of the Pittsburg district. It is true, there has been for a long time more or less done in the use of illuminating gas burned in explosive engines, but in that form it has not reached the position of a fuel "laid on," as it doubt-

less will in future. If the three functions of fuel, light and power can be combined in this mobile medium, flowing almost without pressure in cheap pipes, it will go far to meet the requirements of power distribution in cities, but must always be open to the serious objections that apply to expansive engines as motors, namely, heat, danger, complication, and the amount of detail required to apply the power. In Pittsburg, the effect is already noticeable in numerous small engines fired by means of natural gas and applied to new purposes. I may also mention the fact that these small steam motors seem to have attracted attention to hydraulic motors for the same or analagous purposes, and so far as I could learn, the water machines were thought preferable.

Electrical Transmission.—The reconversion of electrical energy into dynamic force or work has not made the progress that was for a time expected, and it is difficult at this time to conjecture what the future may bring forth. Electricians, for some reason seem to avoid a conversion of their terms into foot-pounds and horse-power, and it is with some difficulty one learns the dynamic value or money value of the amount of power that can be transmitted and applied by a second motor.

This I construe as a significant fact in electrical science, because, if electricians could see "hope and promise" of power-transmission by electrical means, they would long ago have established a system of terms and values concurrent with those employed in dynamics.

Omitting a few exceptional cases, I think the present value of power transmitted is only 40 to 45 per cent. I regret the loss of some interesting notes respecting some French practice in electrical transmission where a much higher duty was claimed.

Hydraulic Transmission.—This brings us to the main subject of the present paper, and to that method of distributing power which, to again use Mr. Tyndal's words, gives "hope and promise" of the greatest success, one which has, so far as I know, no failures to record and which best conserves the requirements for distributed power in our cities.

A history of the origin, rise and progress of hydraulic transmission would be of interest, and in place here, but would oc-

cupy space beyond the limits of the paper, and it must suffice to say that since the earliest applications in the north of England by Darlington, Sir William Armstrong, and others, down to the latest machines of Mr. Tweddel, the art, to so call it, has been one of successful progress. I must also include, as most notable of all, perhaps, the bold applications of special hydraulic transmission in San Francisco.

One of the first things I met with, after coming to this Coast, was, perhaps, the most important hydraulic machine ever constructed. I allude to the immense pumping plant made by the Risdon Iron Works, in 1880, for the Comstock mines. This machinery was, no doubt seen by many who are present, and I am sure every one regrets the very small amount of public information that exists respecting the work. It is creditable to the modesty of the company, as it is a loss to engineering literature, that drawings and descriptions of this great work have not been preserved in public form.

Mr. Moore read a paper on the subject before the Society of Engineers, Glasgow, and had the honor of receiving therefor a special gold medal. I will only remark respecting this machinery that it was contracted under a guarantee of successful performance, cost a quarter of a million of dollars, and was in its leading features a controversion of precedents and common opinions.

The most extensive and complete application of hydraulic power to passenger elevators is in the Palace Hotel in this city. The most extensive application of what is known as the Hastie system, was constructed here, also at the Risdon Iron Works; and the most simple and economical system of commercial elevators in the world are here in this city, to a great extent the result of Mr. Milliken's engineering skill and efforts.

With this much digression, I will point out that water, as a medium for transmitting power, has its chief feature in being non-elastic. Its action is positive and absolute, more so than even shafts and gearing. Also that its compressibility is far less than the hardest metals, so that long after metallic bearings have reached a limit of pressure, or at least pressure with movement, water remains unaffected. In some machinery of recent design, the working pressure is 4,500 pounds to each inch of

area, a force far exceeding the endurance of hardened steel surfaces under movement.

These qualities of positive movement, sustaining extreme pressures, and the facility with which movement is varied by a simple change of area, meet so many requirements in modern industrial art, that hydraulic apparatus now seems indispensable. Its substitution of multiplying and diminishing gearing alone is an important fact in modern mechanics. If a movement of one hundred feet is to be reduced to one foot and the intensity increased accordingly, all that is required are two pistons, one of twelve inches diameter, the other of one inch diameter. Friction is almost eliminated. There is no noise, heat or danger, and the cost of construction is not much, if any more, than for a simple lever having these ratios of movement. The same propositions apply to augmented motion as in the case of high pressure hoists. The hydraulic kind have become cheaper than any other.

I will also point out the function of water as an abutment to guard against return movement. Any elastic medium employed under pressure becomes a source of danger from explosion or release, and besides, does not perform the function of abutment, so desirable in hoisting passengers and goods. So important is this last named matter that it is common in this and other cities to erect steam or gas engines to operate hydraulic apparatus which is placed between the motive power and the hoist. When one estimates the amount of detail such an arrangement involves, they can see the value attached to the inflexible water abutment below the load.

I am of the opinion, judging from present circumstances, that it will be only a short time until there are high-pressure hydraulic systems in all of our large cities. The range of adaptation, to so call it, has been so extended recently that general use seems inevitable. In London there was at first no thought of employing the system for intense pressures, such as is required in punching and shearing metal, pressing, and so on, The pressure in the mains was only 700 pounds to an inch. It was soon discovered that for higher pressure all that was required was differential apparatus, called intensifiers, between the mains and the work, by means of which the normal pressure of 700 pounds could be increased to 5,000 pounds if necessary.

Another and still more important discovery, was that the high-pressure could be reduced, by means of induction nozzles, so as to be employed for fire extinction—so the system has become, so to speak, a vast fire engine. The pressure required for fire purposes is about 65 pounds per inch, or 635 pounds below the pressure of the mains in London or Hull. The fire hydrants, they are called, are simple ejectors having two or more induction nozzles by which the higher pressure is converted to volume at the lower pressure. This feature of the system has great possibilitiey, and may prove a matter of the greatest importance in cities and in private establishments. I am of the opinion that these fire appliances now in use are susceptible of improvement, but even as now developed, the scheme is one of accomplished fact, with an efficiency far exceeding what was expected or thought possible.

I will conclude this portion of my paper with some remarks upon the conversion of hydraulic force into rotary motion.

This problem is the only one that seems to stand in the way of hydraulic power distribution, or is at least the principal one, if we include with it a consumption of water in proportion to the power given off.

For rectilinear motion of all kinds the system is nearly all that can be desired. The loss of power due to irregular or varying resistance is in some cases avoided by mechanism that varies the movement as the resistance; and we have reason to suppose that this method of operating will be further improved in future. There has been already constructed in this city heavy hydraulic winding-gear for mines, wherein the volume of water consumed varied directly as the resistance or load. So the objection is not an insuperable one in so far as reciprocating motions are concerned.

By rotary motion, I mean an adaptation to various manufacturing uses, especially of the lighter kinds, such as occupying the upper floors of business buildings in large cities.

For the accomplishment of this purpose, there are two methods and two classes of motors, each of which in their present state are practicable and reliable under certain conditions. One

is the Water Engine, with reciprocating pistons, such as the Chandler motor-mode in Boston, the Brotherhood motor-mode in London; also the Hastie and Ramsbottom engines mode in England, with many others that might be named. The most successful or enduring of these have solid pistons or plungers, working through packing glands without metallic contact in the water. The Chandler and Hastie engines are so arranged that the stroke, and consequent consumption of water, is governed by the speed in one case and the load in the other, being practically the same thing.

I remember three years ago, when Mr. G. W. Dickie, in answer to the question, "Is there at this time any reliable hydraulic motor to produce rotary motion?" answered "No." I think at the present time he would add a qualification at least, the improvements in this short time having, as I believe, considerably altered the circumstances. Supposing, however, that the improvement in hydraulic pressure engines does not reach present "hope and promise," we have the jet, or impact system, to fall back upon. This method of working has reached an extensive development on the Pacific coast, and Mr. Ross E. Browne of this city, enjoys the distinction of having furnished data respecting such wheels that has since passed into numerous text-books in this and other countries, showing an efficiency far beyond what had been previously supposed.

I am of the opinion that this method of using water to produce rotary motion, is capable of refinement and a much wider adaptation, including control of volume in proportion to resistance—if not completely, or perfectly, as we say, still within such limits as will prevent any considerable waste.

Supposing, however, that such regulation be found impracticable, the loss in driving the machinery employed in light manufactures, will not be much, and the percentage of power transmitted and applied without such regulation will compare favorably with steam or the pneumatic system.

I will now close my paper with some facts pertaining to the hydraulic plants in London and Hull. It was the intention to have included a notice of the works at Portland, Oregon, but circumstances have prevented an intended visit there, besides I

have learned that the apparatus of distribution, or application, it may be called, is substantially the same as that employed in this city, and the pressure is no more than is common in the service of this and other cities, obtained by common direct acting pumps, constructed here by Mr. Dow, who, if present, will, no doubt, add any facts of interest relating to the Portland plant.

THE HULL HYDRAULIC WORKS.

This company was organized in 1880, for supplying power to the docks and warehouses along the water front for lifting goods. The service mains are two miles long. The work was at first considered of an experimental character, and was carried out under the management of Mr. E. B. Ellington, now the engineer of the London Co., to be noticed presently. The amount of water sent out is 156,000 gallons a day, under a pressure of 700 pounds to an inch. The mains are of cast-iron, 6-inch diameter, with flange connections. The leakage in the whole system is only ten gallons an hour. The repairs on the whole plant have not exceeded $150 a year. The cost of raising goods is from one to one and a half cents per long ton for each fifty feet. The price charged for water is from $1 to $1.25 per thousand gallons, the gallon being rated at ten pounds. The efficiency of the compressing engines is 76 per cent., and that of the hoists is in weight lifted 45 per cent. of the indicated engine power. The successful working of this plant induced the organization of the London Co. on a more extended scale.

THE LONDON HYDRAULIC POWER CO.

This company was registered in 1882. In two years later the mains in use were 14 miles long. The water is filtered and sent out at a pressure between 700 and 800 pounds to an inch. It is measured by meters furnished and kept in repair by the company for an annual rental of $5 each.

The company, if required, furnishes machinery of any kind for hoisting, receiving a rental for it, or selling it on the installment plan, if a consumer prefers.

The minimum charge is 25 shillings per quarter; or $2 per month for quantities not exceeding 1,000 gallons. Larger quantities are charged by a sliding scale, from 75 cents to $2 for each 1,000 gallons, owing to the amount consumed. The lowest price named is when the monthly consumption exceeds 35,000 gallons. For quantities exceeding 60,000 gallons a month, the charge is 60 cents per 1,000 gallons.

In some cases the cost for hoisting has been reduced to $\frac{1}{2}$ cent per ton for 50 feet of lift; the efficiency is from 50 to 70 per cent. All parts of the system are subjected to monthly inspection. Leaks are detected at once from the pumping station, and the friction is estimated at 2 to 3 per cent. for each mile.

The engines employed are of the inverted marine type, compound and condensing. The pumps are of the three throw arrangement. The amount of coal burned is 2.4 lbs. per hour for each indicated horse power. The number of consumers at the end of the first year was 31; for the second year 155, and 200 contracts not completed. The main pipes are of cast iron, 6 in. bore, $1\frac{1}{8}$ in. thick.

THE LIVERPOOL HYDRAULIC POWER CO.

This plant now in course of erection will no doubt be the most extensive one of all. The amount of goods to be handled is enormous, and the area concentrated so that one system will probably be made to cover all.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME III.—NOVEMBER 5, 1886.)

MINUTES OF MEETINGS.

REGULAR MEETING.

November 5, 1886.

Vice-President Specht in the chair.

Minutes of preceding meeting read and approved.

The Secretary reported the receipt of a number of volumes of technical works from Colonel C. S. Stewart, U. S. A. On motion of Mr. Manson, the President was requested to appoint a committee of two to wait on Colonel Stewart and thank him for his generous donation to the library.

Colonel Stewart was proposed for honorary membership.

A paper, by John Richards, was read by the Secretary, "On The High Pressure Hydraulic System of Distributing Power in Cities, with some remarks on Other Methods."

Several gentlemen spoke on the subject, and on the suggestion of Mr. Dickie, discussion of the paper was deferred until the next meeting.

Attention was called by the Secretary to the fact that in February last Mr. P. J. Flynn, a member of the Society, had read a paper on a modification of Kutter's formula given in Molesworth's "Engineers' Pocket-Book;" and that when this paper was brought to the attention of Mr. Molesworth, he wrote from Simla, India, to *Van Nostrand's Engineering Magazine* for September, as follows: "Mr. Flynn's criticism of my modification of Kutter's formula for pipes has just reached me. Mr. Flynn is quite correct."

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME IV.—FEBRUARY, 1887.)

MINING DEBRIS IN CALIFORNIA RIVERS.

BY AUG. J. BOWIE, MEM. TECH. SOC.

Read February 4, 1887.

The debris question has within the last few years occupied the attention of the State and Federal Courts of California. The newspapers in the different counties have engaged in endless polemics, until even the casual reader has become more or less acquainted with the subject. In a country pioneered by the miner and made famous by its gold production, it is unfortunate that, with the development of its agricultural resources in certain limited portions of the State, two interests, which should work harmoniously, are at this late date, brought into direct conflict.

The object of this paper is to examine this subject from an impartial standpoint, and to invite a discussion of the ways and means, by which the present deplorable state of affairs may be improved, and to demonstrate from the surveys and explorations already made, and the experience obtained in other parts of the world, what the science of engineering can do to ameliorate the existing situation. The question is, is it practicable to permanently impound debris from the mines, to prevent its entering navigable streams, so that mining may be prosecuted in this

State, without detriment to agricultural interests, and, if practicable, what means should be taken to attain this result; or, can the streams of this State, tributary to the navigable rivers, and into which the mines discharge their debris, be permanently improved, so that navigation will not be impaired, and mining and agricultural interests be made to harmonize.

On the solution of this problem depends the future of the mining interests of the State, in which over one hundred millions of dollars in gravel mining alone, are now invested.

The attention of engineers is here called to this subject, which seems a most fitting one for the consideration and cool deliberation of the members of this Society.

THE MINING FIELD.

The general topography of the great valleys of the San Joaquin and Sacramento rivers, as well as that of the gravel deposits, which flank the west side of the Sierra Nevada, from Plumas in the north to Mariposa county in the south, is so well known to all Californians that a description in detail is unnecessary.

For present purposes, suffice it to say that the great valley forms almost level land, having a roughly elliptical form, trending about N. 30 W., and S. 30 E., and embracing about 18,000 square miles. It lies between latitude 34° 50′ N. near Fort Tejon, and 40° 40′ N. near Shasta, an extreme length of about 450 miles, and an average width of about forty miles.

A longitudinal section of the valley from Redding in the north, to the mouth of the Sacramento river, a distance of 192 miles, shows the fall to be 556 feet, or an average of $2\frac{8}{10}$ feet per mile, while from Kern Lake in the south to the mouth of the San Joaquin, 260 miles, the fall is 282 feet, or an average of 1.08 feet per mile. (See Plate I.)

Cross-sections at right angles to the length of the great valley, show a more or less gradual slope from the foothills of the enclosing ranges towards the Sacramento and San Joaquin rivers.

Between Firebaugh's and Hill's ferries, the ground falls from the foothills to within $4\frac{1}{2}$ miles of the San Joaquin river at the rate of 6 feet per mile; thence it is nearly level to within $\frac{1}{2}$ mile of the river, which it approaches with an ascent of $1\frac{1}{2}$ feet per

mile. At Bantas, the valley is somewhat contracted, and a descent toward the river more rapid, at the rate of 18 feet per mile.

The northern division of the valley is narrower, diminishing to the north. The descent from the edge of the foothills to the Sacramento is more rapid than the corresponding slope in the southern division. From Sacramento City to Folsom at the base of the Sierra, a distance of 18 miles, there is a rise of nearly 200 feet.

NAVIGABLE WATERS AFFECTED BELOW.

The navigable waters are the bays of Suisun, San Pablo and San Francisco, and the Sacramento, San Joaquin and Feather rivers. These channels are more or less affected by detritus, delivered to them by a number of non-navigable tributaries which receive the sands from the gold washings. Those lying to the north of Chico Creek, at present play an unimportant part in the conflict which has arisen, whereas all the streams south of it as far as the Merced river, affect the navigable waters of the State.

The Sacramento river rises in the north, flows in a southerly direction through the great valley, which is flanked on the east by the Sierra Nevada, and on the west by the Coast Range. Like large rivers in broad valleys, the Sacramento runs on an elevated ridge, the banks of the river being decidedly higher than the strip of land on either side. At Colusa this difference of level amounts to as much as twenty feet, and in heavy freshets the water discharges into the adjacent low areas.

On the east side of the Sacramento, close to the river, between the American and Feather, is a basin, the level of which is a number of feet below that of the main river, and which is overflowed in every freshet.

From Marysville Butte to the mouth of the Feather, in an angle here formed with the Sacramento, lies another basin thirty miles in length, which is also subject to overflow at the high stage of the river, and which, from its great storage capacity, exercises an important influence in determining the flood flow of this stream.*

*See Official Report Chief of Engineers to Secretary of War, January 26, 1882, appendix MM. p. 2549.

The streams tributary to the Sacramento are:*

	Drainage area.
The American	1,899 sq. miles
Bear	287 " "
Feather (at Oroville)	3,654 " "
Yuba (with sundry areas)	1,452 " "

The Sacramento Valley has an area of 4,769 miles, classified as follows:†

Designation.	Area Sq. Miles.
High hill lands	55.50
Low hill of rolling land near foot-hills	650.00
Dry plains above reach of all overflow	2,321.45
" " subject to occasional overflow from tributary streams	450.00
Lands subject to flooding, etc., etc	1,254.00
River slough and channel surface of perennial streams	38.05
Total	4,769.00 sq m.

DRAINAGE AREAS.

The catchment areas, with the drainage tributary to the Sacramento, are more than two and one-half times greater than the area of the valley itself.‡ The Sierra Nevada side, (drained by the American, Bear, Feather and Yuba rivers, Butte, Chico, Rock, Deer, Mill and Antelope creeks, has an area of 8,843 square miles, with elevations as high as 11,000 feet) receives annually from 24 to 102 inches of precipitation in form of rain and snow, while the rainfall in the valley, over an area of 4,769 square miles, averages from 18 to 20 inches. The Coast Range with an area of 3,075 square miles, flanking the valley on the west has less precipitation than on the Sierra, while the mountainous district at the northern end of the Sacramento plain, which includes Mt. Shasta (14,440 feet high) in its area of 5,616 square miles, has a rainfall varying from 30 to 110 inches.

*See Physical Data and Statistics of California, by Wm. Hammond Hall, State Engineer, pp. 394, 395.

†State Engineer's Report 1880, pp. 7 and 8.

‡State Engineer's Report, Jan. 21, 1880, p. 8.

The area drained by Pitt River at its junction with McCloud River, excluding Goose Lake basin, is 4,597 square miles. The total area of the Sacramento basin at Collinsville, excluding Goose Lake basin, aggregates 26,187 square miles. At its head is Mount Shasta, 14,440 feet high. In this high drainage basin there is a precipitation of rain in three or four months which reaches 90 inches or more. Three-fourths of the area of this basin is mountainous, the greater part of it being subject to a very considerable rainfall, and which may be averaged for the whole mountain area at 35 or 40 inches, and for the area of the basin at about 30 inches.*

About half the total rainfall in latitude 38° occurs in the months of November and December. Going north precipitation increases, while toward the south it decreases. The rain-clouds come almost exclusively from the south and southwest. There is not a single permanent flowing stream on the west side of the valley of the San Joaquin from the Coast Range, and nearly the same is true of the Sacramento Valley, although Putah, Cache and Stony creeks discharge at times a large quantity of water.

It is clear that the capacity of the water-ways of this section of the State is wholly inadequate to discharge at high flood the drainage of the country.

The San Joaquin River has its source in the south, and flows in a northwesterly direction through the valley, uniting with the Sacramento River at the upper or eastern end of Suisun bay. The southern or high Sierra, which flanks the southeastern portion of the San Joaquin valley between parallels 36° and 37° 50′, has its drainage effected by means of Kern, King and San Joaquin rivers. The elevation of the main crest is from 12,000 to 13,000 feet high, with numerous points over 14,000 feet, but none reaching 15,000 feet. The descent on the western slope averages 250 feet per mile.

Kern river drains a larger area than any stream flowing from the western slope of the Sierra with the exception of the Feather river. Its catchment area is 2,345 square miles. King's river,

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*See Physical Data and Statistics of California, by Wm. Hammond Hall, State Engineer, p. 394.

which drains the country to the north of Kern, has a catchment area of 1,742 square miles, while the Kaweah, which drains the region between Kern and King's, has a catchment area of 698 square miles.

The entire region north of King's river, is drained by the San Joaquin. The principal streams emptying into this river and flowing down the western slope of the Sierra, are the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes. South of the Merced are the Chowchilla and Fresno, which rise in the foothills, and likewise drain into the San Joaquin.

Chowchilla and sundry areas—catchment area	328	sq. miles.
Fresno " " " "	299	" "

The Merced and Tuolumne rise in what is known as the Middle High Sierra.

Merced and sundry areas—catchment area	1166	sq. miles.
Tuolumne " " " "	1613	" "

From the Tuolumne north, the drainage area of the streams flowing into the San Joaquin from the western slope of the Sierras is as follows:*

Stanislaus river (rising in Silver Mt.)	1065	sq. miles.
Calaveras " (" near Grove of Big Trees)	556	" "
Mokelumne " (" east of Silver Mt.)	657	" "
Cosumnes "	580	" "

The Sacramento and San Joaquin rivers, near their mouths at the northeastern extremity of Suisun bay, where they join tide water, flow through a delta of considerable extent, the surface of which is below the level of flood tide. The Strait of Carquinez connects Suisun Bay with San Pablo Bay, which opens into San Francisco Bay, these rivers and bays forming a continuous channel, connecting with the Pacific Ocean through the Golden Gate.

The auriferous deposits of all kinds worked by the miners, and which affect the region described, occur on the western slope of the Sierra Nevada from Siskiyou in the north, parallel with the

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*For details see Whitney's Auriferous Gravels of California, pp. 9, 10, 11, and Physical Data and Statistics of California, by Wm. Hammond Hall, p. 396.

crest of the Sierra, to Tehachapi in the south, a distance of nearly 400 miles. The width of this mining area is from 20 to 40 miles, extending from the plains or edge of the valley, to altitudes of 5,000 to 6,000 feet. The largest amount of mining in proportion to area, is comprised between Chico creek on the north and Merced river on the south, a distance of 150 miles.

Having briefly outlined the principal topographical features of the mining regions, as well as those of the valleys affected by mining operations, the questions which next present themselves are:

1st. The extent and value, of the auriferous workable deposits on the western flank of the Sierra Nevada, and the present condition of the mining industry, as affected by the late decisions of the State and Federal courts.

2d. The amount of material heretofore discharged from the mines annually into the valleys.

3d. What is the extent of the damages so far as known, due as is supposed to the flow of detritus from the mines, and other causes; how much land has been injured; what is its value; the time occupied in its temporary destruction, and the yield of the mines during that period; what is the extent of deposits of debris in the mountain channels above and below the foothills; what do the estimates show, and what are the deductions therefrom; how do the ancient and present lines of drainage resemble each other; how have the navigable rivers been affected, and what do the past and recent surveys of these streams show; the causes tending to diminish the tidal prism of San Francisco Bay; what is the commercial value of the river channels for steamers and vessels, compared with the railroad lines of communication as demonstrated by the transportation of freight.

These several questions will now be answered categorically.

THE MINING REGIONS.

The extent of the mining region which flanks the valley already referred to, aggregates nearly 450 miles in length, and

approximates 40 miles in width. The value of the quartz and gravel deposits within that large area of 18,000 square miles, it is practically impossible to state, but some idea of the same may be formed by showing their product either in the aggregate or annually. It is within bounds to state that these gold fields have produced since their discovery in 1849, over twelve hundred millions of dollars, which is a permanent addition to the material wealth of the country, consequent upon the imperishable value of the precious metal, without referring to its stimulating effect upon all other industries. The annual production is approximately shown in the following table:

PRODUCE OF GOLD IN THE UNITED STATES FROM ITS DISCOVERY IN CALIFORNIA, JANUARY, 1848, TO JUNE 30, 1883, STATED IN FISCAL YEARS.*

YEARS.	Gold Produced in State of California.	Gold Produced in other States and Territories	Total Produce of Gold Mines.	Gold Contained in Silver Produce.	Grand Total Produce from all Sources.
1848	$245,301	$851,274	$1,096,575	.....	$1,096,575
1849	10,151,360	927,684	11,079 044	.....	11,079,044
	10,396,661	1,778,958	12,175,619		12,175,619
1850	41,273,106	665,217	41,938,323	.....	41,938,323
1851	75,938,232	602,380	76,540,612	.....	76,540,612
1852	81,294,700	712,263	82,006,963	.....	82,006,963
1853	67,613,487	508,564	68,122,051	.....	68,122,051
1854	69,433,931	251,627	69,685,558	.....	69,685,558
	335,553,456	2,740,051	338,293,507		338,293,507
1855	55,485,395	312,364	55,797,759	.....	55,797,759
1856	57,509,411	369,031	57,878,442	.....	57,878,442
1857	43,628,172	143,053	43,771,225	.....	43,771,225
1858	46,591,140	386,028	46,977,168	.....	46,977,168
1859	45,846,599	366,957	46,213,556	.....	46,213,556
	249,060,717	1,577,433	250,638,150		250,638,150
1860	44,095,163	875,878	44,971,041	$50,000	45 021,041
1861	41,884,995	2,831,895	44,716,890	800,000	45,516,890
1862	38,854,668	3,989,210	42,843,878	2,150,000	44,993,878
1863	23,501,736	7,474,808	30,976,544	4,350,000	35,326 544
1864	24,071,423	8,372,115	32,443,538	5,300,000	37,743,538
	172,407,985	23,543,906	195,951,891	12,650,000	208,601,891
1865	17,930 858	9,920,244	27,851,102	5,500,000	33,351,102
1866	17,123,867	12,086,941	29,210,808	4,650,000	33,860,808
1867	18,265,452	13,169,117	31,434,569	5,700,000	37,134,569
1868	17,555.867	7,942,116	25,497,983	4.000,000	29,497,983
1869	18,229,014	7,607,698	25,836,742	3,550,000	29,386,742
	89,105,088	50,726,116	139,831,204	23,400,00	163,231,204
1870	17,458,133	7,907,569	25,365,702	3,700,000	29,065,702
1871	17,477,885	7,813,419	25,291,304	5,500,000	30,791,304
1872	15,482,194	6,975,843	22,458,037	6,900,000	29,358,037
1873	15,019,210	7,213,768	22,232,978	12,000,000	34,232,978
1874	17,264,836	6,863,012	24,127,848	11,500,000	35,627,848
	82,702,258	36,773,611	119,475,869	39,600,000	159,075,869
1875	16,876,009	5,572,299	22,448,308	13,800,000	36,248,308
1876	15,610,723	5,511,272	21,121,995	18,500,000	39,621,995
1877	16,501,268	8,862,694	25,363,962	18,300,000	43,663,962
1878	18,839,141	9,755,213	28,594,354	19,000,000	47,594,354
1879	19,626,654	10,421,948	30,048,602	9,000,000	39,048,602
	87,453,795	40,123,426	127,577,221	78,600,000	206,177,221
1880	20,030,761	9,209,033	29,239,794	6,000,000	35,239,794
1881	19,223,155	10,139,136	29,362,291	6,000,000	35,362,291
1882	17,146,416	8,468,141	25,611,557	5,000,000	30,614,557
1883	17,256,873	8,586,141	25,843,014	4,500,000	30,343,014
	73,657,205	36,402,451	110,059,656	21,500,000	131,559,656
TOTALS..	$1,100,337,165	$193,665,952	$1,294,003,117	$175,750,000	$1,469,753,117

*See App. A, "Bowie's Hydraulic Mining."
This table was carefully compiled by Louis A. Garnett, Esq.

PRODUCE OF GOLD IN CALIFORNIA.

From January 30, 1883, to December 30, 1883, $5,648,000. Estimated from Rep. Director of Mint.—1884.

For calendar year 1884, $13,600,000. Rep. Director of the Mint, 1886, p. 51.
" " " 1885, $12,700,000. " " " " " "
" " " 1886, $12,579,356. Wells, Fargo & Co.

The total gold product of this State during the last year does not exceed thirteen million dollars. The falling off is readily accounted for by the stoppage of the gravel mines.

The estimated amounts of workable gold bearing gravel deposits on the west flank of the Sierra Nevada in California, are as follows:

	Cubic Yards.
Upper and Lower Feather River, large amounts	Unestimated
Yuba and tributaries	700,000,000
Bear and tributaries	50,000,000
American and tributaries	75,000,000
Cosumnes, principally at Hill Top, from 11,000,000 to 12,000,000, say	11,500,000
Mokelumne, enormous amounts, but not favorably situated	Unestimated
Calaveras, upper portion	Unestimated
Calaveras, lower portion, principally at Jenny Lind	22,500,000
Stanislaus	Unestimated
Tuolumne, large amounts	Unestimated

"The quantity of auriferous gravel now remaining on the flanks of the Sierra Nevada is practically unlimited. If it were all workable, its exhaustion would tax the energies of miners for many generations. No practical end could be served by an attempt to estimate the aggregate mass.

"For several good reasons, only a comparatively small portion of the whole, can be regarded as workable under existing conditions.

"The workable quantity in several basins is in a certain sense subject to estimate between limits in an approximate way. Such an estimate is very desirable in order to give a basis for an opinion as to the extent, cost, and duration of any system which may be adopted for the purpose of remedying evils consequent upon mining."*

The present condition of the gravel mining interest in this State is best shown by the late decisions of the State and Federal courts, and cannot perhaps be better indicated than by quoting the final decree of Judge Sawyer, U. S. Circuit

*Forty-seventh Congress, first Session House of Representatives. Ex. Doc. No. 98, p. 35.

Court, Ninth Circuit, District of California, in the well known suit of Woodruff *vs.* North Bloomfield Gravel Mining Co., *et al.*

United States of America, Circuit Court of the United States, Ninth Circuit, District of California.

Edwards Woodruff *vs.* The North Bloomfield Gravel Mining Co.; the Milton Water and Mining Co.; the Omega Gold Mining and Ditch Co., the Conley and Gowell Consolidated Mining Co.; the Excelsior Water and Mining Co.; D. B. Chadwick and Oscar Campbell, under the firm name of Chadwick & Campbell; —— Conly, and ——— Gowell.

In the Circuit Court of the United States, Ninth Circuit, District of California. Edwards Woodruff, complainant, *vs.* North Bloomfield Gravel Mining Company and others, defendants, in Equity.

FINAL DECREE.

This cause came on to be heard upon the bill, answer, depositions and the other proceedings in the cause, and was argued by counsel.

On consideration whereof, it is by the Court ordered, adjudged and decreed as follows, to wit:

That as to defendant, the Conly and Gowell Consolidated Mining Company, the bill be, and it is hereby dismissed.

And that the defendants herein, to wit: the "North Bloomfield Gravel Mining Company," and its officers, agents, servants and employees, and each and all of them, and the "Milton Water and Mining Company," and its officers, agents, servants and employees, and each and all of them, and the "Omega Gold Mining and Ditch Company," and its officers, agents, servants and employees, and each and all of them, and the "Excelsior Water and Mining Company," and its officers, agents, servants and employees, and each and all of them, and also B. D. Chadwick, sued herein by the name of D. B. Chadwick and O. D. Campbell and the firm or partnership of Chadwick & Campbell, composed of said two last named persons, and their and each and all of their agents, servants and employees, and Hannah Conly, as executrix of the last will and testament of John Conly, deceased, and who

is substituted as a defendant in place of said decedent, and Orrin Gowell, and their and each and all of their servants, agents and employees, are perpetually enjoined and restrained from discharging or dumping into the Yuba river, or into any of its forks or branches, or into any stream tributary to said river or any of its forks or branches, and especially into Deer Creek, Sucker Flat Ravine, Humbug Creek, Scotchman's Creek, any of the tailings, bowlders, cobble stones, gravel, sand, clay, debris or refuse matter from any of the tracts of mineral land or mines described in the complaint. And also from causing or suffering to flow into said rivers, creeks, or tributary streams aforesaid therefrom, any of the tailings, bowlders, cobble stones, gravel, sand, clay, or refuse matter resulting or arising from mining thereon. *And, also, from allowing others to use the water supply of said several mines or mining claims, or any part thereof, for the purpose of washing into said rivers and streams, any earth, rocks, bowlders, clay, sand or solid material contained in any placer or gravel ground or mine.*

2. That the complainant recover of the defendants above-named, save the Conly & Gowell Consolidated Mining Company, his costs in this suit, taxed at.....and the same be paid by said defendants to complainant.

3. That the defendants, or either of them, may, at any time hereafter, apply to this Court upon due notice to the complainant or Geo. Cadwallader, Esq., his solicitor, for a modification or suspension of this injunction as to such defendants or defendant so applying, upon any showing which the Court may deem sufficient that the conditions have been so changed that the discharge of such mining debris by said parties or party, so applying, into said streams, or any of them, may be resumed or otherwise conducted, so as not to create, or continue, or contribute to create or continue the nuisance complained of, or a nuisance of a similar character, and so as not to injure or damage, or contribute to injure or damage said complainant, or upon any other grounds hereafter arising satisfactory to the Court. And for the purposes aforesaid, the Court hereby reserves the power to mod-

ify or suspend said injunction, in whole or in part, as the exigencies and equities of the case hereafter arising, may require.

January 23, 1884.

(Signed) LORENZO SAWYER, Circuit Judge.

Endorsed: Filed and entered January 23, 1884.

(Signed) L. S. B. SAWYER, Clerk.

I, Lorenzo S. B. Sawyer, Clerk of the Circuit Court of the United States for the District of California, do hereby certify the foregoing to be a full, true and correct copy of the Final Decree in the therein entitled cause, now on file and of record in said Circuit Court.

Attest my hand and seal of said Circuit Court, this 23d day of January, A. D., 1884. L. S. B. SAWYER, Clerk.

[SEAL] By (signed) F. D. Moncton, Deputy Clerk.

From the decree, which speaks for itself, and under which it is most difficult if not impossible to mine at all, no appeal has been taken, and it is therefore, as it now stands, the law of our State. The result is, that the principal hydraulic mines in the State have been closed, and suits have been instituted against parties for drift mining, and in one instance, the North Bloomfield Gravel Mining Company has been adjudged guilty of contempt of court, and fined heavily for violating this injunction, by drift mining. That this decision of the court applies to all classes or kinds of mining, there can be no doubt.

ESTIMATES OF MATERIAL DISCHARGED FROM THE MINES.

2. The amount of material discharged annually from the mines into the valleys has been investigated at different times, and the following table from the State Engineer's Report, Part III, p. 24, 1880, shows the result of his inquiry into the extent of hydraulic mining within the Sacramento basin:

NAME OF STREAM.	Water Used 24 hour M. I.	Duty per inch per cu. yd.	Material Washed in cubic yds.
Table Mountain	1,016,000	3½	3,556,000
Feather River	3,625,000	3½	12,687,500
Yuba River	6,379,000	3½	22,326,500
Bear River	1,850,000	3	5,550,000
Auburn Ravine, Roseville Creek	340,000	2	680,000
American River	1,912,000	4½	8,604,000
	15,122,000	.....	53,404,000

"Thus it is seen that 15,122,000 miners' (24 hour) inches of water were used in hydraulic mining per annum on the streams which drain into the Sacramento Valley, and 53,404,000 cubic yards of material of all kinds are washed out by its use. * * * This estimate does not include mining on the upper Sacramento, for from this no bad results are noticeable so far as known."

The quantities of water used in 1880 in the Sacramento basin were returned by the County Assessors and published as an appendix to the State Engineer's Report of 1881.

This report was supplemented by information collected by the State Engineer department, and summarized in Ex. Doc. No. 98, 47th Congress, 1st Session House of Representatives, as follows:

Name of Stream.	Water 24 hour M. I.	Duty per inch in cu. yd.	Amount Moved cubic yds.
Table Mountain and Dry Creek.....	833,250	3½	2,916,375
Butte Creek.....	24,000	3	84,000
Feather River	1,259,363	3½	4,407,770
Yuba River	5,458,171	3½	19,103,598
Bear River.....	1,117,082	3	3,351,246
Dry Creek No. 2	44,229	3	132,687
American River.....	1,914,500	4½	8,615,250
	10,650,595	.....	38,610,926

A comparison of these tables shows differences of as much as 66 per cent. in some of the estimates of the quantity of material mined in certain localities. Taken as a whole, there is a difference of nearly 30 per cent. less in the quantity as estimated in accordance with the assessor's water returns, and the estimate given in State Engineer's Report of 1880, Part III, p. 24, of which latter amount, the report says: "I have estimated that about 24 per cent. of the material from the Feather River has been carried off; * * * 40 per cent. of the material from the American River. * * * Of the 18,100,000 cubic yards of material brought down the Sacramento Valley in suspension, 4,900,000 cubic yards are due to natural wash.

The information respecting the rivers south of the American, collected by the United States Government, is given in the following table:

TABLE II.—*Estimate of material moved annually.*

RIVER.	MINE.	DITCH.	Water used, 24-hour inches.	Cubic yards moved per 24-hour inch.	Total number cubic yards moved.	Summary, cubic yards.	REMARKS.
Cosumnes	Hill Top	American and Sacramento	456,000	2½	1,140,000	.....	
	Various placers	Jordan	48,000	.....	40,000	1,180,000	Part of water used for power.
Dry Creek	Irish Hill	American and Sacramento	162,000	2½	405,000	405,000	
Mule Creek	Various small placers	Johnson's	38,000	1	38,000	38,000	
Sutter Creek	Various placers and hydraulic	Amador Canal	54,750	1	54,750	.....	
	Volcano hydraulic	Volcano	365,000	2½	912,500	.....	
	Various placers	Johnson's	38,000	1	38,000	1,005,250	
Jackson Creek	Various placers and hydraulic, M.	Amador Canal Company	127,750	1	127,750	.....	
	Near Buena Vista, at head of Jackson Creek	Dougherty	43,400	1	43,400	171,150	
Mokelumne	Near Campo Seco, Camanche and Stockton Ridge	Mokelumne	61,000	2	122,000	.....	
	Railroad Flat, head South Fork	Clark's	45,000	2	90,000	.....	
	Near Lancha Plana and Camanche.	Murray & Dougherty	118,500	.....	60,000	272,000	Part of water used for power.
Calaveras	Near Jenny Lind	Salt Spring Vally Reservation and Union	365,000	2	730,000	.....	
	Chile Gulch and Jesu Maria Fork of Calaveras	Mokelumne	200,750	2½	501,875	.....	
	Juniper, at Dogtown, San Domingo Creek	Union	365,000	2½	912,500	.....	
	Near Mokelumne Hill	Cook Brothers	45,000	2	90,000	2,234,375	
Stanislaus	Near Knight's Ferry	(small)	38,720	2	77,440	77,440	
Tuolumne	La Grange and Patricksville	La Grange	812,500	2½	2,031,250	2,031,250	7,414,465 cubic yards. Total at present.
	On Upper Tuolumne, to begin operating soon.	**Golden Rock.**	**730,000**	**2½**	**1,825,000**	**3,856,250**	**9,239,465 cubic yards. Total in future.**

In reviewing these statements, it is impossible not to be surprised at the great differences between them. The data are official, and as such have been used in the courts. From later information on this subject, more reliable data have been obtained for the region of the Yuba draining into the Sacramento basin, where the largest and most important gravel mines are located, and the greatest quantity of water used.

Names of Mines.	Miners' 24-hour inches.	Cubic yards per inch.	Total amount of gravel moved.
North Bloomfield	800,000	.....	.....
Milton Co	500,000	.....	.....
Omega	150,000	.....	.....
Connelly & Gowell	100,000	3½	.....
Sailor Flat	250,000	.....	.....
Blue Tent	250,000	.....	.....
Eureka Lake	700,000	.....	.....
South Yuba	450,000	.....	.....
Smaller claims	50,000	.....	.....
	3,250,000	.....	11,375,000

In respect to the damage said to have been done to that section of the country, which appears to be principally affected by mining detritus—namely, the Yuba and Feather rivers and tributaries — the official report of 1880 shows that 43,546 acres suffered a depreciation in value of two millions five hundred and ninety-seven thousand six hundred and thirty-four dollars.* (See Plate II.)

"The estimates made with respect to property depreciation are based altogether on hearsay evidence."†

This, it appears, is the amount of land stated as having been injured by mining and other causes, including the natural denudation of the country during the last thirty-six years. The estimated loss to the State in taxes upon this land is placed at $7,145.18 annually.‡

"There are," says the State Engineer, "lands in large bodies which, as they stand now, are more valuable than before the stream beds were raised * * * have been rendered

* State Engineer's Report, Part III, p. 20.
† Report State Engineer, 1880, Part III, p. 22.
‡ Report State Engineer, 1880, Part III, p. 20.

moist and tillable in a high degree by the raising of the sub-surface waters. But I have not had time to look far enough into this matter to estimate the extent of such changes."*

The yield, on the other hand, of the mines tributary to this one section of the State, has probably exceeded $600,000,000.†

Estimates of the amounts of deposits of detritus in the tributaries of the navigable waters of the State have been made, to some of which attention has been called. Many estimates have been attempted by different engineers, and some of these stand of record in the Federal and State courts. Notably may be mentioned the evidence given in the case of Keyes *vs.* Little York Gold Washing and Water Co., where the amount of deposit in Bear River, above the plain, was placed at 86,000,000 cubic yards, and below that point to the mouth of the river, 36,000,000 cubic yards.

From the State Engineer's Report of 1880, the estimate of the deposits in 1879 in the Yuba basin shows that there were 48,462,100 cubic yards stored in the cañons of the South, Middle and Main Forks of the Yuba, and the Yuba proper, above Yuba Mill, and 23,284,000 in the Yuba from the Yuba Mill to County bridge at Marysville—a distance of 15 miles.‡ In this last mentioned distance the river flows over a large area of former bottom lands. Originally, the water was confined by well defined banks, "but at present these and the adjoining lands have been covered from one to twenty feet deep with mining detritus."§ This latter amount of 25 square miles or 16,000 acres forms a part of the 43,000 acres already referred to as being damaged.

To ascertain the quantity of material which had been washed down from the mines draining into the Yuba river, and discharged upon the lands below, estimates were made by actual measurement of the cubical contents of the excavations at the more important mines, while by relative comparison and actual inspection of the pits those of the smaller ones were approximated.‖

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*Report State Engineer, 1880, Part III, p. 22.

† The loss to the State in taxes consequent upon closing the mines has been vastly in excess of $7,143.18 loss in taxes upon the land injured. It is believed that the increase in value of the large bodies of land above referred to rendered "moist and tillable," has been sufficient to fully reimburse the State taxes, so that the loss to the State in taxes has been solely in decreased value of the mining property.

‡ State Engineer's Report, Part III, 1880, pp. 60-61, inclusive. Also, see testimony in Woodruff *vs.* North Bloomfield et al., pp. 62-63.

§ See State Engineer's Report. 1880, Part III, p. 59.

‖ See Woodruff *vs.* North Bloomfield et al., pp. 72 and 519.

The following tables show in detail the estimates given by the engineers employed by the plaintiff in the Woodruff suit.*

MINES ON THE SOUTH FORK.

Mines.	Cubic Yds. Mined.
Omega	1,780,000
Diamond Creek	70,000
Curtley & Co.	24,000
Merrills	850,000
Alpha	1,620,000
Gold Hill Phelps	220,000
Relief Hill	6,930,000
North Bloomfield	18,800,000
Old pits near North Bloomfield	250,000
Brockmeyer & Co.	580,000
South of Powder House	380,000
Pit southwest of last one	240,000
Columbia Hill	17,350,000
Blue Tent	2,420,000
Sailor Flat	1,800,000
Grizzly Hill	360,000
Kennebec	500,000
French Corral	10,700,000
Total washings on South Fork	64,874,000

NORTH FORK.

	Cubic Yds. Mined.
Above Downieville	50,000
Scammon & Weil at Eureka	1,110,000
Morse	200,000
North of Eureka	880,000
Big Cañon Creek	290,000
Morristown	500,000
Slate Creek, above Portwine and Pits	2,300,000
At Portwine	880,000
Near St. Louis	96,000
Spanish Flat	120,000
Gibsonville	75,000
Pleasant Mountain	80,000
Whisky Diggings	65,000
Crittenden & Co., Howland Flat	36,000
Cox & Co.	140,000
Pits near Howland Flat	170,000
At La Porte	3,450,000

* See Woodruff *vs.* North Bloomfield et al., p. 543.

Scales Diggings	350,000
Union Hill	50,000
Poverty Hill	880,000
Secret Diggings	290,000
Galena and Young's Hill	2,000,000
American and Railroad Hills	1,500,000
Total at North Fork	15,512,000

MIDDLE FORK.

	Cubic Yds. Mined.
Woolsey Flat	1,600,000
Moore's Flat	4,000,000
Snow Point	500,000
Orleans Flat	200,000
Camptonville	2,420,000
Chips' Flat	60,000
Alleghany City	100,000
North San Juan	11,290,000
American Mine, Sebastopol	4,000,000
Badger Hill, Cherokee Flat	2,000,000
Total washings Middle Fork	26,170,000

MINES AT DEER CREEK.

At or near Nevada City	10,700,000
Rough and Ready	130,000
Randolph Flat	120,000
Murchies, above Nevada City	100,000
Gray & Co	220,000
Ashburner & Baker	160,000
Sundry small pits	400,000
Mooney Flat	755,000
Total at Deer Creek	12,585,000

MINES AT MAIN FORK, MAIN YUBA, ABOVE INITIAL POINT OF MANSON ALLARDT SURVEY, NEAR SMARTSVILLE.

	Cubic Yds. Mined
Manzanita Hill	7,800,000
At and near Birchville	10,860,000
Smartsville upper pit	17,000,000
Total	35,660,000

MINES ON MAIN YUBA, BELOW INITIAL POINT.

At Timbuctoo	20,260,000
At Sucker Flat	1,000,000
Total	21,260,000

RECAPITULATION.

Washings at South Fork	64,874,000
Washings at North Fork	15,512,000
Washings at Middle Fork	26,170,000
Washings at Deer Creek	12,585,000
Washings Main Fork Main Yuba, above initial point	35,660,000
Washings Main Yuba, below initial point	21,260,000
Grand total	176,061,000

It appears from the evidence in this celebrated debris suit, that about thirty per cent. of all the material which has been mined has passed down into the main river, both in suspension and moving along the bottoms of the channels. It was also stated in the plaintiff's evidence, that a much greater mass is moving along the bottom than near the surface,* and that on July 29, 1882, when the water passing Marysville aggregated twenty thousand miner's inches, or 44,600,000 cubic feet daily, samples of it taken near the surface showed that 3¼ cubic yards of solid material were being transported in suspension per inch of water,† amounting to 65,000 cubic yards per day in suspension. These quantities appear to vary with the season of the year, the amount of water, and the guesses of the engineer.

Thirty per cent. of the 176,061,000 cubic yards, shows that 52,818,300 cubic yards passed on down into the main rivers; 48,462,100 cubic yards are stated to be stored in the cañons, making a total of 101,280,400 cubic yards of detritus thus accounted for, leaving seventy-four millions seven hundred and eighty thousand six hundred cubic yards of material deposited between the foot-hills and the mouth of the Yuba.

One million thirty-two thousand five hundred and thirty cubic yards (1,032,530) of material are necessary to raise one square mile one foot in height. If the foregoing estimate of the quantity stored below the foot-hills be correct, the total fill at present should be only 2.90 feet, over the area of 25 square miles, or the 16,000 acres which have already been spoken of as damaged.

It is a well known fact that at Smartsville the depth of the debris is at least 125 feet; at Point de Guerre not less than 80

* Testimony Woodruff *vs*, North Bloomfield et al., pp. 97, 463.

† Testimony of Woodruff *vs*. North Bloomfield et al., p. 206.

feet (?), and at the mouth of the Yuba from 15 to 30 feet. As far as can be inferred, the average depth of the deposit over the area mentioned, may be approximated from 15 to 25 feet, (?) which would make the aggregate amount of material deposited in this locality vary from 387,200,000 cubic yards to 645,000,000.

As the total quantity of material mined, in accordance with the foregoing statements is only 176,000,000, thirty (30) per cent. (or 53,000,000 cubic yards) of which has passed off in suspension, and 48,000,000 have been found stored in the cañons, leaving only 74,000,000 unaccounted for, the resulting 313,000,000, or 569,000,000 cubic yards of debris which are said to be spread over the 16,000 acres, must be due to other causes than mining, or these statements are absolutely incorrect.

There is no doubt that these differences show, that the main accumulation is due to natural erosion or unknown causes, otherwise they can only be the result of an attempt to reconstruct by a futile effort of the imagination, a topography of the past.

The data to which attention has been called, are not quoted in a captious spirit, but as matters of record, which stand to-day as official information, used and accepted by the State and Federal Courts of California. Glaringly incorrect as they are, judgments have been rendered upon them throwing thousands of people out of employment, and destroying many millions of property. All such estimates are, at best, only guesses. Circumstances have not permitted estimates in their true sense to be made, which could have been done only at a great cost of time and money, which latter has not been forthcoming for this purpose.

The sediment determinations of the material transported by the several streams, show on their faces to any engineer just what they are, and that no reliance can be placed upon them. Even supposing that each test was made with the greatest care and attention, the number is too small, places too scattered, and the period of time over which the samples were taken, too short to make these determinations of any real assistance or value in ascertaining the sediment discharge of any of these rivers.

As illustrative of these facts, nothing could throw more discredit on the value of the sediment determination than a quota-

tion from Vol. XII, p. 9080, of the testimony in the suit of Woodruff *vs.* The North Bloomfield Mining Co. *et al.*, wherein a letter to the Secretary of War, from one of the learned counsel for the plaintiff, states, that "the high water discharge (ordinary) of the Sacramento River is 100,000 cubic feet per second, charged to the extent of more than one per cent. with hydraulic mining sand, besides a heavy current of it flowing at the bottom."

Let us analyze this statement. 100,000 cubic feet per second =6,000,000 cubic feet per minute. 6,000,000 cubic feet per minute $\times$1440=8,640,000,000 cubic feet discharged per 24 hours. One per cent. of this amount=86,400,000 cubic feet of material transported every 24 hours. Reducing this to yards, we have 3,200,000 cubic yards of material being daily carried off in suspension by the Sacramento River, without taking into consideration "what rolls along the bottom." To put this in a mild form, if this river were to run but 12 days during the year, 38,000,000 cubic yards would be carried off in suspension alone, which about equals the total amount of material mined (estimated) in an entire year in the area tributary to the Sacramento River, not one-half of which quantity ever reaches the navigable streams. From this showing the river must be well scoured out, and at the end of the month ought to be very clean and clear of all debris. This letter, which appears in the testimony, was reinforced in the evidence, by an extraordinary statement by engineers of the plaintiff, to the effect that "for every cubic yard of material carried in suspension by the water, there were three cubic yards carried along the bottom of the stream."* Now adding this additional amount to the material carried in suspension, there are 12,800,000 cubic yards discharged by the Sacramento River every 24 hours, or, in three days, a quantity equal to the entire amount of debris which has been washed from the mines in a year, and for the year 20 times more than Humphrey and Abbott state is the quantity of debris passing out of the Mississippi in same length of time. Further comment is unnecessary.

THE ANCIENT AND PRESENT LINES OF DRAINAGE.

The area drained by the present streams does not differ essentially from that drained by the pliocene rivers. In the tertiary

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*Testimony Woodruff *vs.* North Bloomfield et. al., p. 463.

epoch, the Sierra Nevada Range was the same as it now is, so far as concerns the general elevation and the position and direction of the principal river basins into which its western slope is divided.*

The existence of those larger channels shows that the water flow from corresponding areas was greater during that period than it now is. There is no certainty that there was the same number of streams reaching the valley in pliocene times as at present. It is probable that some of the larger streams joined together at greater elevations, concentrating their waters before entering the Sacramento Valley. The two large rivers flowing from the Sierra in the pliocene period are to-day represented by the American and the Yuba. These streams, which are now practically rivulets, can be traced far down into the valley by the widely spread deposits of gravel and the usual accompanying volcanic masses. From the great width of the main channels of the gravel epoch, steepness of their grade and depth of the deposits, it is quite clear that the volume to-day discharged by the present streams is insignificant when compared with that of the pliocene period.

It is said that in early days the present streams were clear running waters in their ordinary stages between high banks. The casual observer noted no change in their beds or slopes, until the flood of 1862, when the water from the mountains is said to have carried masses of material into the valleys, raising the beds of the streams and flooding the adjacent lowlands.

Subsequent floods at intervals of six or seven years, apparently increased the evil more markedly, but it was not until 1869 that the low water reading of the Sacramento tidal gauge showed an increase of 2 $\frac{9}{10}$ feet above the zero.

The inquiry naturally suggests itself as to the sources whence this material came. It is a well established fact, that in the early period of placer mining, over one hundred thousand men were engaged in washing for gold in the section of country tributary to the Sacramento River, and necessarily an enormous quantity of material was discharged into the smaller streams or tributaries. These accumulations, and those from subsequent mining, were

* The Auriferous Gravels of California.—Whitney, p. 342.

undoubtedly transferred into the streams below, during the flood period, and assisted in raising the bed of the channel. This once accomplished, the slightest subsequent change was readily noticed, and every evil accruing therefrom was thereafter immediately attributed to hydraulic mining.

Here it seems proper to investigate this question, and to see if the damage to the Sacramento River is wholly due to the mines.

Surveys by the Government have been made of the navigable waters of the Sacramento and its subsidiary channels, aggregating a distance of two hundred and sixty miles. These surveys are in detail, so there exists a full record of the stream. The name, Upper River, is applied to the hundred-mile stretch lying above Colusa. The banks of this section of the stream are by no means permanent. The river shifts more or less with every flood, and upon its subsidence the navigable channel is found in a number of places to have changed position.*

The only good banks of the Upper River are those of an ancient and larger stream, which, at the big cut-off, are one and a-half miles apart, and at Sam Soule's Bar are two-thirds of a mile from one another, the river between these points touching the banks. The hard banks are about the level of high water. Between these places, some five feet lower, there is an alluvial bottom covered with a forest growth of sycamores and cottonwoods, through which the river meanders. With its various changes trees are uprooted and masses of material are washed with them into the stream below.

There are numerous tributaries with heavy grades, coming principally from the Coast range, carrying large amounts of gravel, which are discharged into the Upper River. These tributaries are subject to heavy freshets, which are, however, of short duration.

Stony Creek, which enters the river about forty-five miles above Colusa, draining 760 square miles of territory subject to enormous floods, is said to have a flood discharge of 80,000 cubic

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*Appendix KK. Annual Report of Chief Engineer, 1880, p. 2237.

feet per second. It carries very large gravel to the river in considerable quantities.*

Reed's Creek, Redbank Creek, Elder Creek and Thomas Creek, are all gravel-bearing streams, discharging into the Sacramento from the Coast range, whereas from the Sierra Nevada side no gravel can be said to enter the stream.

The fall of the Upper River from Red Bluff to Colusa varies from 14 to 30 inches per mile, and from below Colusa for the first 35 miles, it averages only 5½ inches. The following table shows the average grade per mile for the different parts of the river:

LOW WATER PROFILE, SACRAMENTO RIVER, CALIFORNIA.†

STATIONS.	Distance from Red Bluff.	Elevation above low water at New York Landing.	Average fall per mile.
	Feet.	Feet.	Feet.
Red Bluff	0	244.54	2.05
Last Chance	20,000	236.73	2.57
Sacramento Bar	53,000	220.67	3.47
Foot of Saw Mill Rapids	80,000	202.77	0.79
Tehama	93,000	200.82	0.68
Head of Tehama Rapids	95,000	200.56	8.41
Foot of Tehama Rapids	100,000	192.55	1.66
Head of Captain Jane's Rapids	120,000	186.23	2.83
Squaw Hill	153,000	168.48	2.83
Merrill's Wheat Landing	170,000	159.29	0.92
Head of Gazette Chute	185,000	156.66	1.89
Hoodlum Chute	203,000	150.14	2.12
Head of Sam Soulé Bar	230,000	139.23	7.53
Foot of Sam Soulé Bar	234,000	134.49	1.75
Collay's Ferry	239,000	132.82	0.84
Bidwell's Landing	270,000	127.80	1.62
Chico Landing	298,000	119.18	1.82
Munroville	326,000	109.50	1.34
Deadman's Bar	356,000	101.86	1.73
Jacinto	384,000	92.66	1.93
Head of Pike's Cut-off	408,000	83 86	1.91
Foot of Pike's Cut-off	418,000	80.22	1.26
Battle City	448,000	73 00	1.19
Princeton	475 000	66.90	1.37
John Bogg's Landing	496,000	61.41	1.14
Calden's Landing	529,000	54.25	0 872
Colusa	595,500	43.20	0.177
Winn's Landing	779,500	27.00	0.328
Knight's Landing	891,500	20.00	0.138
Mouth of Feather River	1,043,500	16.00	0.325
Sacramento City	1,153,000	9.35	0.201
Haycock Shoal	1,204,000	7.40	0.160
Head of Grand Island	1,294,000	4.66	0.263
Rio Vista	1,367,000	1.01	0.062
Collinsville	1,440,000	0.15	0.050
New York Landing, Suisun Bay	1,455,500	0.00	.....

*See Appendix KK, to Report of Chief Engineer, 1880, p. 2239. Also report of Wm. H. Brown, engineer of the Sacramento Valley Irrigation and Navigation Canal, 1867, p. 18.

† The Annual Report of Chief of Engineers for 1880, Appendix K. K.

The low water discharge of the Sacramento River at the city of Sacramento below the entrance of all its tributaries, is from 5,000 to 6,000 cubic feet per second.* The Feather discharges 1,800 cubic feet per second, and 200 cubic feet per second come from the American River, leaving 4,000 cubic feet per second as the supply from the Upper River.

Between Stony Creek and Butte Slough, the Sacramento River is very irregular in width and depth. The land on both sides of it is from one to ten feet below the river, the banks of which readily cave. The greatest depression is from two to seven miles distant from the channel. During periods of ordinary high flood, the channel is inadequate to discharge the water of the river, which consequently leaves its bed and flows into Butte basin, into which flow also, the waters from Butte and Table Mountain creeks, emptying thence through Sutter basin into the river lower down.

During flood periods "the tributary streams sometimes enter the river with power sufficient to control the main stream for a time. In some cases they actually form a dam by their entrance, interrupting the stream and sending the current both up and down. They attack the bank of the river opposite to their own mouths and crumble it with a mighty force. At the same time they leave in the bed of the main river large deposits of material, which acting as a barrier direct the main stream into a new course, and force it to attack the less resisting banks. This temporary control of the main river by a tributary is illustrated in a number of cases. Stony Creek, in the Upper River, does it in flood, and lower down the same thing occurs at the mouth of the American and Feather rivers, and still lower at the mouth of Cache Creek Slough."†

Following the main river down from Butte Creek, with its crooked course between firm banks, through whirls and eddies, to Sycamore Slough, at Knight's Landing, a distance of 49.8 miles, low basins are observed flanking it on both sides, from three to seven miles distant, and from five to fifteen feet below the elevation of its bank. The ground falls away rapidly

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* For details see Physical Data and Statistics of California pp. 412, 415, 476, 477.

† Appendix KK, Chief of Engineers, Rep. 1880. p. 2240.

from the banks to the basins, and in places the fall is as much as 12 feet per 1,000.

The inclination of the river bed for this stretch is less than between Stony Creek and Butte Slough. The channel is materially smaller, and does not discharge to exceed one-half the waters brought to it in ordinary high flood, although it receives no drainage from the east side. Sutter basin lies between the Sacramento and Feather rivers, each acting as a main drain for that section of the valley. The drainage from the west empties into Colusa Basin, whose natural outlet is through Lower Sycamore Slough into the river.

"In ordinary flood periods there is no drainage for this basin, "as the flood elevation at the lower end of this drain is 13 feet "above the general elevation of the valley."* So that the Coast Range drainage can only be carried off after the river flow subsides.

From Knight's Landing to the mouth of the Feather the distance, on an air line, is only 5.5 miles; but by the river, with its contracted and irregular channel with a slight inclination, it is 14.8 miles, both sides of which are flanked by low basins—the Sutter on the north and the Yolo on the south side. The river has been partly leveed, but crevasses are of annual occurrence, and the floods pour into both basins.

Descending the Sacramento below the Feather to the American, a distance of 19.7 miles, the channel is noticeably better and larger. The banks are generally good, only one notably bad place, "The Six-mile Shoal," being encountered; and, "notwithstanding," says the State Engineer, "the changes alluded to [raising of bed by mining detritus, etc.], it is a better one to deal with in this division than the other mentioned."† The Yolo basin flanks it on the west and the American basin on the east. The levees are poor, and the flood waters discharge into both basins.

From the mouth of the American River to the head of Grand Island, 27.7 miles, the Sacramento receives no tributaries, the river being flanked by the Yolo basin on the west and the

* Report of the State Engineer, Part 1, p. 19.

† State Engineer's Report, 1880, p. 19.

Mokelumne basin on the east. The surface of the ground falls away from the river banks, necessitating levees to protect the land. The levees on the east side are said to be well built, while those on the west side are poorly constructed. The slope of the channel in the upper portion of this section is greater than in the preceding one, but at the lower end, as it approaches a bifurcation of the stream at Grand Island, the inclination decreases.

Grand Island, which divides the stream, is surrounded by a levee. That portion of the river flowing around its west side is called Steamboat Slough, and that on the east side is designated as Old River. These branches subsequently unite, the distance by Old River channel being 18 miles, and by Steamboat Slough 10 miles.

Grand Island, from its position, has the effect of reducing the grade of the channel, shoaling the stream and checking the flow of the water, which is demonstrated by the fact that at "flood stage for miles above the head of Grand Island, the grade of the water line is only 0.28 feet per mile, while below the same point at the same stage on Steamboat Slough the grade is 0.75 feet per mile, and Old River is 0.43 feet per mile."*

From Grand Island to the junction of the Sacramento and the San Joaquin, opposite Collinsville, a distance of 15.8 miles, the river flows in one channel, except opposite Rio Vista, where Ward Island makes a division of about a mile. The waters of Old River, Steamboat Slough and those from Yolo basin, west of the river, (from the overflow of the Sacramento on that side below Knight's Landing and from the floods of Cache and other creeks which drain the Coast Range,) are here united. The channel is irregular in depth, with a notably narrow place and a wide shallow stretch which obstruct flood waters, while the banks are generally low and swampy. Opposite Collinsville, at the junction of the two rivers, there is a large shoal which obstructs the flood waters from the Sacramento.

It is evident, from what has been stated, that local defects in the channel of the Sacramento have always prevented its discharging the waters from ordinary high flood. "For 106 miles above

*State Engineer's Report, 1880, Part I, p. 26.

Butte Slough there is a channel of greater grade and greater dimension than there is for 64½ miles below the mouth of Feather River. The Six-mile, Haycock's, Hog's Back, Iron House and Newtown shoals, lower down, bar the free passage of flood water, as do the deeper and better formed reaches of channel above and below them."*

The defective levee system has impaired the capacity of the channel and disturbed the equilibrium of the streams, causing eddies, whirls and bars. In the lower reaches of the river the levee system has throttled the stream, thus reducing the grade and the rate of discharge and increasing the rate of deposit. The crevasses have occasioned divisions of the stream, and the flood-carrying capacity is diminished by the shoaling which occurs below each division and scouring action is greatly impaired. The discharge of sands from the mining operations has reduced the carrying capacities of the stream, and has also caused changes in the channels below, but their precipitation and retention in the last mentioned channels has been greatly increased by the causes which have been mentioned above.†

The washing of the river banks and the levees by the action of waves, steamers and vessels, and the erosion due to tidal action, do not appear ever to have been touched upon in relation to the shoaling and depositing of material in the Sacramento and other navigable streams. As illustrative of the action of vessels and steamers, can be cited Mr. Ure, who says that "on the Clyde, steamers, going at the rate of eight or nine miles an hour, produce a swell which commences to rise when the vessel is two or three miles off," * * * "the swell, increasing as the steamer approaches, becoming a wave of translation, breaking on the mud walls nearly abreast of the vessel, following her on her course as a violent breaking wave measuring sometimes 8 to 10 feet from the hollow in the channel to the crest on the wall."‡ These waves have been denominated the waves of displacement.

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*State Engineer's Report, 1880, p. 10.

†State Engineer's Report, Part I, p. 11.

NOTE.—The general details of the description of the Sacramento have been condensed from the official reports of the State Engineer, Wm. Hammond Hall.

‡Canal and River Engineering, by Davis Stevenson, pp. 20, 21.

Data for estimating the amount of material contributed annually, by the general erosion and denudation of the surrounding country, to the streams of this State do not exist.

The investigations on the subject of erosion, made by T. Mellard Reade, C. E., show that the annual discharge of solids in solution equals for the Rhine 92 3 tons per square mile; for the Rhone, at Avignon, 232 tons per square mile; and for the Danube, 72.7 tons per square mile. He considers that over the entire world, there may be every year, dissolved by rain, 100 tons of rocky matter per English square mile of surface.*

According to Messrs. Humphreys and Abbott, the average proportion of sediment contained in the waters of the Mississippi is $\frac{1}{1500}$ by weight, or $\frac{1}{2900}$ by volume. But besides the matter held in suspension, they observed that there was a certain amount of material being pushed along the bottom of the river. The conclusions they reached were that the Mississippi discharged annually 19,500 000 million cubic feet of water, and that the weight of mud annually aggregated 813,500 million pounds. The total annual contributions of earthy matter, whether in suspension or moving along the bottom, they estimated to equal a prism 268 feet in height, with a base of one square mile — which, reduced to Reade's basis, shows an annual erosion of 240 tons per square mile.

The Ganges, according to Everest, carries, during four months of flood, earthy matter in a proportion of $\frac{1}{428}$ by weight, the mean average for the year being $\frac{1}{510}$ by weight.

The topography of the great valley has resulted from a complicated series of operations. The change of level on different parts of its surface was the beginning of erosion, and the work of the rain and running streams at once commenced to show. The steeper the grade the greater has been the eroding power of the water, which increased in a rapid ratio with the increase of velocity. Therefore in this subaerial erosion, the quantity of rain which falls is an element of prime importance.

In a region like the Sierra, which flanks the great valley, on

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*See address to Liverpool Geological Society, 1877.

the east, other things being equal, on account of the large precipitation, erosion will be the greatest. This will be modified by the condition of the country, character of the rocks, joints and cleavage planes, lines of stratification, tendency of the rock to decompose on exposure to the air, amount and rapidity of the variation of temperature, and finally the form of depression in which the water begins to run as the result of the preceding orographic disturbances.

"In applying," says Prof. Whitney, "these considerations to the resulting forms of valley sections, we come to the following conclusions:

"As a general rule, large streams in correspondingly broad valleys, with cross-sections closely approaching straight lines, the amount of the depression is but trifling, compared with the lineal extent included within the edges of the water-shed. The higher we ascend into the mountains the smaller the stream."*

The water of a river, "in its efforts to attain a uniform flow," is constantly cutting away the narrow places and filling in the larger sections, and as the volume discharged by the several sections is the same in any given stage of water, though the areas are different, the mean velocity at the different places is constantly varying; consequently material, such as sand and sediment, which would be detrimental to the bed of a stream, is carried in discontinuous suspension. This result must necessarily follow when a stream flowing through a plain, increases its length, thus diminishing its fall and consequently reduces its velocity.† The solid matter which it carries is deposited in its channel wherever the current is checked, and the bed is thus raised. Hence, the tendency of a river is to deteriorate when left to itself, and the discharge capacity of its channel becomes less.

When a river has partially adjusted itself to any given stage, the stage changes, and cutting and filling at new points again begin. As illustrative of the changes due to great variation of

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* Whitney's Auriferous Grades of the Sierra Nevada, pp. 339–340.

See Three Problems in River Physics, by Prof. J. B. Johnson.—Van Nostrand's Engineering, September, 1885.

† See Report of Mississippi River Commission for 1881, Plate 7, p. 120.

width, can be mentioned an actual case at Plumb Point, on the Mississippi River, where the following extremes were found in 1879 on a reach eight miles in length.*

		WIDE SECTION.	NARROW SECTION.
Surface width in feet,	High water	8,840.	1,680.
	Low water	7,380.	1,375.
Mean depth in feet,	High water	23.9	60.7
	Low water	6.0	23.9
Area of section in square feet,	High water	260,000.	94,500.
	Low water	30,227.	68,500.
Mean velocity in ft. per sec.,	High water	3.67	10.1
	Low water	2.65	1.15
Fall per mile in feet,	High water	0.26	1.75
	Low water	1.15	0.07

The low-water wide section had a mean velocity of 2.65 feet per second, while the narrow section had a mean velocity of 1.15 feet per second. At the high-water stage the conditions are reversed. The wide section has a mean velocity of 3.67 feet per second, while the narrow section has a mean velocity of 10.1 feet per second. The wide section was some eight miles above the narrow one. The river is thus seen to be cutting out the shoal and filling up the pool in low water, and cutting out the pool and filling on the succeeding shoal in high water.

Between November 13 and January 3 the total scour over the reach above referred to was 350,000,000 cubic feet, enough to cover 1 square mile to the depth of 12½ feet. "It is not uncommon for the shoal places to be built up as much as from 6 to 10 feet in time of high water, so that the bottom of the river is then higher than the surface of the water will be, after this same fill has been cut out by succeeding low water. In other words, the river bed is a succession of narrow, deep pools, alternating with wide shoals. The pools are in the bends, and the shoals are on the crossings. The shoals are like so many dams, 50 to 75 feet in height, stretching across the river bottom say every 10 miles. In high water these dams are built several feet higher, and the narrow pools are dug several feet deeper. In time of low water

*See Report of Mississippi River Commission for 1881, p. 69.

the dams are scoured down several feet, and the material deposited in the succeeding pool. What is true of the Mississippi River on a large scale is true on every stream flowing on friable bed, on a corresponding scale."*

It is estimated that the denudation of the Sacramento basin due to natural causes at the rate of that of the Po would amount to 43,000,000 cubic yards per annum; at the Rhone rate, 21,-950,000 cubic yards; at the Ganges rate, 13,230,000 cubic yards; at the Mississippi rate, 5,592,110 cubic yards. Applying the Po rate of denudation (which more closely resembles the Sacramento River and valley in all its physical features than any other river) to the mining field of the Yuba, Bear and American rivers, there would be an annual contribution from this source aggregating 6,000,000 cubic yards of material and a correspondingly larger amount from the agricultural regions.†

A glance at the charts‡ shows that large contributions to land building have been made at the delta of the San Joaquin and Sacramento rivers. This delta may be taken to include all land classed as swamp and overflowed, comprising in all more than 500 square miles. In this area are the following islands: Union, Roberts, Bouldin, Staten, Andrus, Brannan, Tyler, Grand, Schoolcraft, Twitchell and Sherman. All of this land is of comparatively recent formation, and is the product of natural action, affected inappreciably, if at all, by mining operations. This land is made by deposits of sediment brought by the two rivers mentioned, with the aid of their numerous tributaries, from the high lands which flank their respective valleys on either side. Of the truth of this statement no one can have any doubt. The period of time during which this depositing action has been at work is of course unknown. Further study would doubtless show it to be a probable conclusion, that other areas of considerable dimensions lying in the great valley of California, now claimed as high lands, were at a remote period marsh or tule lands, and have since been raised by silt deposited

*Three Problems in River Physics, by Prof. J. B. Johnson, from Proc. Am. Assoc. for the Advancement of Science.

† House of Representatives, 47th Congress, 1st Session.—Ex. Doc. No. 98, p. 27.

‡ See Plate III.

by floods from adjacent streams. This process of formation may to-day be witnessed at the outfall of Putah and Cache creeks in the Yolo basin, which each year reclaim a portion of the low-lying land by deposition of detritus from lands lying above.

It may reasonably be concluded that agricultural operations, by breaking up the soil, favor its movements down the hill slopes to the channels of the creeks. One can, therefore, feel assured that land building is now progressing, due to natural drainage action, by reason of extended cultivation of the soil, at a more rapid rate than has hitherto been witnessed.

At one time the marsh lands surrounding the bays of San Francisco and San Pablo were wastes, while the neighboring hills were covered with grass. It is to be observed that no streams larger than creeks enter these bays, and it is a fact worthy of note that wherever a creek discharges, a large area of marsh land is found. The settlement of the country, the breaking up of the soil, and the great fall of the streams and rain, have favored the erosion and transportation of earthy materials. To these and natural causes may be attributed the making of more than two-thirds of the new land within the limits of the bay, including the entire southern end of San Francisco Bay, where both shores are fringed by a marsh from one to three miles wide, and also the marshes in San Pablo Bay. All the marsh and overflowed land in the vicinity of the outlet into the Bay of Napa and Petaluma creeks comes from the deposits of Petaluma, Napa and Sonoma creeks. The marshes below Napa, and the deposits in the vicinity of Mare Island Strait near the Navy Yard, are due to the discharge from Napa Creek. The land made along the shores of the rivers and adjacent to their mouths, together with the low marshes which are very extensive, are the result of the work of the rivers. "The formation of these littoral marshes, their gradual conversion by successive growth of deposits into upland, and whatever portion of the shoaling in Suisun Bay not due to local creeks, represent the past work of the rivers. These, then, are the great natural causes, favored by peculiarities of climate and topography, which have in past ages reduced the bay to a small proportion of its original area. These causes are still at work, and

must continue to work, whatever other conditions prevail. It is impossible now to say how fast these changes are going on. So far as the small creeks are concerned, the inquiry hardly seems to be practical, for the reason that we are powerless to prevent their action."*

A subject which has attracted but little attention is the destruction of the forests on the mountain sides, and the unrestricted pasturage of large herds of stock, but particularly of sheep. These two causes have, year by year, increased the natural denudation not only in the mining regions but in the southern portion of the State, where little or no mining is prosecuted. It is especially noticeable in the Feather River basin, to which attention has been called in the United States official reports. The Pacheco Valley, in Contra Costa county, is another instance near our city where the result of agricultural operations is very pronounced, as the lower portion of this valley has been raised nearly ten feet, and there is not a mine of any kind on its drainage area.

It is a well known fact that at Caliente, the Southern Pacific Railroad Company has of late been compelled to raise the level of its tracks, which a few years ago were placed, as it was supposed, 10 to 12 feet above all probable danger. To-day the beds of the streams have raised to the level of the former railroad beds, and the company has been forced to change the line. Still further south, at Los Angeles, the river which flows through the city of Los Angeles, has of late years raised its bed so that the surrounding country is now threatened with an overflow should a wet season occur. The San Gabriel, Santa Anna and San Diego rivers are also, in flood time, literally rivers of sand; yet there is not a mine on any of them.

The cause of these troubles is directly attributable, in addition to natural causes, to the cutting of trees on the mountain sides, and the unrestricted pasturage of stock, and also to the work of the farmer.

Attention has been called to these different facts for the purpose of showing what the natural agencies are, which affect this

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* House of Representatives, 46th Congress, 3d Session.—Ex. Doc. No. 93, p. 5.

State. It is therefore not astonishing that the Sacramento River or any other stream in the valley should overflow its banks and submerge the country during flood season. But it is not possible to see how it can be averted, and left to itself, from natural causes alone, this condition of affairs cannot be otherwise than annually progressively worse.

The raising of the beds of these drainage channels or rivers, thus affecting more or less with each succeeding flood, the adjacent land, which is lower than the channels themselves, is the damage which is attributed to hydraulic mining, without any consideration of the causes which, in accordance with the law of nature, act more constantly and on a much grander scale. Had there been no mining, the same result would have followed.

The annexed profile illustrates the relative grades of the pliocene and present channels of the American and Yuba rivers, showing what has occurred from natural causes, independent of any additions from mining. (See Plate IV.)

HOW THE NAVIGABLE STREAMS HAVE BEEN EFFECTED.

The navigable waters are the channels of the great bay, the Feather, Sacramento and San Joaquin rivers. There are no old surveys available with which recent charts can be compared, so as to show an accurate record of the changes which have taken place during the past generation. From partial records, and well established facts developed by inquiry and investigations, a fair general comparison can be made of the former and present conditions of the Sacramento River before the entrance into it of mining detritus. The gauge readings of the low stage of the Sacramento River observed at Sacramento at different periods since 1849, show a continuous rise with some anomalies. The zero of the gauge at the foot of K street, was placed in 1849 at 3.85 feet above the mean of lowest low water at the junction of the Sacramento and San Joaquin rivers. The gauge readings of the low water stage were as follows:*

* House of Representatives, 47th Congress, 1 Session (Ex. doc. No. 98, p. 29.)

	Feet.
1849 low water reading	Zero
1854 " " "	1.75
1869 " " "	2.9
1874 " " "	4.9
1875 " " "	4.5
1876 " " "	7.1
1877 " " "	5.3
1878 " " "	5.5
1879 " " "	5.8
1880 " " "	7.4
1881 " " "	6 5
1885 " " "	7.5

It is evident that the low water plane of the Sacramento has been raised about 7 feet since 1849. This elevation of the bed has affected the tidal influence as high up as the mouth of the Feather River, 25 miles above Sacramento. This influence, which formerly amounted to 2 feet at Sacramento, is now no longer visible above Heacock's Shoals, 9 miles below Sacramento. The tide within the last 30 years rose on these shoals as much as 3 feet. The Russian Embarcadero, 10 miles below Sacramento, was formerly 3 feet out of water at the low stage, but in 1878 it was 1½ feet under water, showing a rise of 4½ feet.

The low water level of 1852 was fixed at Green's Ferry, 3 miles above Courtland by the level at which the branches of a tree were cut off in that year, for the accommodation of a ferry boat. This level is 4 feet below the level of 1878. Corroborative evidence of the rise of the bed is also afforded by trustworthy evidence at Hog's Back and at Ida Island. The changes of level at Sacramento in 1880, were 5 to 5½ feet; at the mouth of the Feather, 3 or 4 feet; and at the head of Steamboat Slough, 1½ to 2½ feet.* The rise of the low water plane indicates fillings, not so much in the pools of the river as on the shoals. All the shoals below Sacramento are found to consist of detritus from all sources.

Assuming that the filling in of the pools, has kept pace with the rise in the low water plane, the general filling of the bed between the Feather River and Sacramento City, a distance of

* Report of State Engineer, 1880, p. 31.

25 miles, would be 5 feet, and for the 60 miles below Sacramento an average of about 3 feet, exclusive of the deposit in Steamboat Slough.

The official survey of 1854, covering about 2 miles of the river in front of Sacramento City, was compared by the State Engineer with the condition of the river in 1879, showing a maximum fill of 35 feet and an average of 15 feet.*

Resurveys of these sections in 1884 show the changes which have since taken place here.†

Locality.	Loss of Sectional area.		Area, 1885.
	1854–1878	1878–1885	
	Square feet.		
Section opp, U st	8,000	3,550	2,970
Section opp. M st	8,070	2,640	3,290
Section opp. W st	11,040	2,760	2,840
Section opp. K. st	9,520	3,320	2,700
85 ft. above R. R. bridge	14,980	2,110	2,890
800 ft. below mouth of American River	11,970	2,970	2,310

Estimates in detail of the aggregate deposits in the Sacramento River occurring during the last 35 years are not possible, as specific information similar to the above cannot be given for the whole river.

Steamboat Slough, formerly used for navigation, has now an average depth of only 4 feet at low tide, and navigation through it has therefore been abandoned. Old River is still navigable, and, although the effective depth is somewhat less, owing to the partial decrease of tidal influence, the bars at low water do not appear to have altered, though an increase in the slope of the stream will ultimately affect them.

Although there have been large deposits between Sacramento City and the mouth of the Feather River, "the best accessible testimony indicates that there has been no change of effective depth worthy of notice."‡

The Feather River never was navigable above Yuba City, op-

* State Engineer's Report, 1880, p. 31.

† Annual Report Chief of Engineers, U. S. A., 1886.

‡ House of Representatives, 47th Congress, 1st Session.—Ex. Doc. No. 98, p. 31.

posite Marysville. It is still navigable to the same place, although the bed of the river has raised about 15 feet above low water at that point. The increase at the mouth of that river is said to be 3 or 4 feet. In 1841, the Sacramento River was surveyed by Wilkes' Exploring Expedition. Lieut. Ringgold was in charge of this department, Lieut. Alden accompanying him. According to Wilkes' account, "it was a season of drought, little rain having fallen during the previous winter. * * * Capt. Sutter's crops had failed for want of rain. * * * Ten miles above Sutter's Camp (present site of Sacramento) the launch was left, as they were unable to cross the bar, (probably Russian Crossing). The boats could not enter Feather River without grounding on a bar across its mouth."* No mention is made of the existence of tide. United States Government investigations show that in 1878, the fill at the mouth of the Feather was five feet.†

From this and the data already given, it is seen that the slope of the Feather River is increased four inches to the mile, which shows that there is a fill in this portion of the river of at least ten feet.

The San Joaquin does not show evidence of important changes in the channel.‡

In respect to the causes tending to diminish the tidal area or prism of the Bay of San Francisco and the commercial value of the harbor of San Francisco, the official report published by the House of Representatives (46th Congress, 3d Session; Ex. Doc. No. 93), shows—

1st. That the bar at the entrance of San Francisco harbor has suffered no injury between 1855 and 1873. A later survey, made in 1884, shows no difference in the depth of water on the bar at that date. If anything, the water was a little deeper, and no deposits of mud are known to exist anywhere this side of the 100 fathom line, which is 20 miles beyond the bar.

2d. Surveys of the ship channels of a portion of San Pablo

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* Wilkes' Exploring Expedition.

† House of Representatives, 47th Congress, 1st Session.—Ex. Doc. No. 98, p. 31.

‡Forty-seventh Congress, 1st Session, House of Representatives.—Ex. Doc. No. 98, p. 29.

Bay made in 1855, 1863, 1878, show that between 1855 and 1863, no deposits of importance were made in the channels. The surveys of 1863 and 1878 show that over an area of 24⅓ square miles a deposit of 76,025,000 cubic yards was made in that interval, occurring mainly on the flanks of the channels, and narrowing it, showing an average filling of about 3 feet, but without affecting to any great extent the ruling depth, and that 6 cross sections between the 18 feet contours, show a reduction of 22 per cent. of the main width of 1855.

3d. That 3½ miles on the Sacramento, near its mouth, and 1 mile at the mouth of the San Joaquin, show a deposit of two million cubic yards in the Sacramento, and 500,000 in the San Joaquin between the years 1867 and 1878, also in the corresponding period the area of the shoals in Suisun Bay has been extended, and during different periods large deposits have been formed in the Straits of Carquinez.

A review of the situation shows that the drainage of 62,086* square miles reaches the Pacific Ocean through the Golden Gate, of which 26,187* square miles are drained by the Sacramento and its tributaries, 31,895* by the San Joaquin, which latter, in times of flood, is slightly augmented by an overflow of the basin of Tulare Lake. The remaining drainage area of 4,004* miles comes from the small creeks which enter the great bay along its shore. The amount of water descending the western slope of the Sierras into the great valley varies exceedingly from season to season, and year to year. The rivers have two seasons of high water, namely: the winter season, during the rains, and the spring season, when the snow melts. The low water discharge of the Sacramento approximates 6,000 cubic feet per second, and that of the San Joaquin during a corresponding period is about 1,000 feet per second.

While the snow is melting in the spring the aggregate discharge of these two streams approximates 100,000 cubic feet a second, though during the winter flood for a short period they may deliver 200,000 or 300,000 cubic feet per second. The great bay is 75 miles long. The northern part is known as San Pablo

* The figures marked with asterisk see Physical Data and Statistics of California, by W. H. Hall, C. E., pp. 387, 388.

and Suisun bays, and the southern portion as San Francisco Bay. Official surveys show their respective areas to be as follows:*

	Area within the 6 ft. contour. Acres.	Total area within high water lines. Acres.	Area between the 6 ft. contour and H. W. line. Acres.
San Francisco Bay	89,975	173,163	83,188
San Pablo and Straits	47,668	76,250	28,582
Suisun Bay	14,002	31,937	17,935

The total tidal area tributary to the Golden Gate (including the estuaries of the river and marsh lands) at extreme high water is 740 square miles, while the area of the bays at ordinary high water is only 440 square miles, and the area of the marsh lands (level of ordinary high water) is 300 square miles.

The marsh land is distributed between the bays in the proportions of 12, 9 and 10 respectively, to San Francisco Bay ($\frac{2}{5}$), San Pablo Bay and the Straits, and Suisun Bay ($\frac{1}{3}$).

Of the 440 square miles already mentioned, 200 square miles have a low water depth of less than 6 feet.

The map of the Harbor Commission, prepared by T. J. Arnold, C. E., shows that the State of California has conveyed to different parties or corporations, a strip of land of irregular width, extending the whole length of San Francisco Bay and along the greater part of San Pablo Bay, and aggregating 67,465 acres, or 105 square miles, all lying below ordinary high water mark. A statute of March 31st, 1868, amended April 1st, 1870, "provided for the sale of all lands remaining unsold in the City and County of San Francisco, and within five miles of the exterior boundaries to the depth of 9 feet at extreme low water."† (See Plate V.)

This covers an extreme length of 26 miles in the bays of San Francisco and San Pablo, amounting to nearly one-quarter of the whole high water area of the bay.

* Measured by J. R. Mauran, C. E.

† House of Representatives, 46th Congress, 3d Session.—Ex. Doc. No. 93, p. 7.

The present condition, then, of the great bay, San Francisco, San Pablo and Suisun, is, that of the 740 square miles (when its bordering marshes are covered) of tidal area, 300 square miles have been made land (not overflowed by ordinary tides) by natural causes, and of the 440 square miles remaining, one-quarter has been disposedof by the State to corporations and others. The location of this portion is in San Francisco and San Pablo bays, in the very locality where it has its greatest value as a tidal reservoir. Of the unsold area of tide water lands, with a depth of less than 6 feet low water mark, it can be stated that this depth will in time be reduced to nothing under the action of natural causes.*

On the Oakland side, the United States Government has extended a solid stone jetty for a total length of 9,750 feet. The Central Pacific Railroad Company has also extended a pier $2\frac{3}{4}$ miles long, from the shore to the 24-foot contour. This mole, outside of a depth of 9 feet at low water, is of timber on bents of piles 8 or 10 feet apart. Inside of this depth there is a solid filling, about 6,600 feet long and 75 feet wide on top. South of these works is a second pier, constructed by the South Pacific Coast Railroad, of still greater length.

The extension of these fillings directly into the bay can have no other effect than the shoaling of all land between *terra firma* and their *terminii.*

The large quantity of material which is washed down from the mountain ranges in the rear of Oakland and the country between it and the bay, and from other sources, which would otherwise be distributed over the entire area of the bay will be here deposited, and the scouring which would be occasioned by the ebb and flow of the tide, is here effectually stopped. No more efficient way of filling in the bay of San Francisco, and making land on the Oakland side, could have possibly been undertaken, with better assurance of success, than what is being accomplished by these moles. In fact, in river engineering it is by means of such works that the banks of streams are made to fill up. Dead water ensues on

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* See Ex. Doc. No. 93, House of Representatives.—46th Congress, 3d Session, p. 3.

both sides of the projection, and deposits of all kinds assist in making land.

It is only a question of time for the bay to be filled in on the Oakland side, along the great length of the moles described. The policy of such work has never been questioned, as the attention of the State at large has been centered on other subjects. The filling or shoaling of the bays, coming from the sediment discharged from the Sacramento and San Joaquin rivers, is insignificant when compared with the fill occasioned from the other causes mentioned.

The waters of San Francisco Bay enter and discharge through the Golden Gate (which measures between Fort Point and Lime Point at a low-water cross-section of 902,000 square feet), with a maximum depth of sixty-three fathoms. At the Heads, between Point Bonita and Point Lobos, the low-water cross-section is 1,101,615 square feet, with a maximum depth of twenty-five fathoms. The bar is fourteen miles long, and has a low-water section of 2,439,000 square feet, and corresponding depth of from ten to three and three-fourths fathoms.*

The average fall of the large ebb tide in San Francisco Bay is five feet, and the average duty of the ebb current to produce the changes of level, supposing the bay to be completely emptied, must be fully 3,000,000 cubic feet per second, or for the period of maximum action of the ebb, more than 6,000,000 cubic feet per second. With the spring tides, the outflow is greater. The landward drainage, therefore, when compared with the volume contributed by the tide, is absolutely insignificant. The average stages of the river-flow is hardly one-tenth of the tidal volume, and even a flood of 400,000 cubic feet per second would not half equal the volume that the tide supplies and removes daily. The daily ebb and flow of the tide is nearly four times as large as the ordinary discharge of the Mississippi, and over two-thirds of its maximum flood discharge. The scouring action of this enormous volume of water is what preserves the bay and what makes the channels and the estuaries of the San Joaquin and Sacramento rivers.†

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* See Vol. III, Transactions of the Technical Society of the Pacific Coast, Jan. and Feb., p. 12, ¶ 4–3.

† Transactions of the Tech. Soc. of the Pacific Coast, Vol. III., pp. 3 and 4.

The commercial value of the river channels for vessels and steamers, when compared with the railroad lines of communication, is indicated by the transportation of freight and passengers. The following table shows the total amount of freight and passengers transported by steamers and vessels on the Sacramento River and tributaries for the year ending June 30, 1886:

BY BOATS OF THE SACRAMENTO TRANSPORTATION COMPANY.

	Tons.
From San Francisco to Sacramento—Merchandise	17,698
Lumber	25,000
Coal	3,760
Sacramento to San Francisco—Brick	55,500
Merchandise	3,760
San Francisco to Upper Sacramento—Merchandise	12,575
Lumber	8,500
From Sacramento to Upper Sacramento—Merchandise	2,750
From Upper River—Wheat, barley and flour	94,549
Wool, broom corn and hay	3,750
Wood	25,000

BY BOATS OF SOUTHERN PACIFIC COMPANY.

Between San Francisco and Sacramento—North	37,639
Between Sacramento and San Francisco—South	15,679

TRADING BOAT "NEPONSET."

From Sacramento to Upper Sacramento River—Merchandise	1,500
From Upper River to Sacramento—Wheat and barley	1,000

S. F. S. CO. AND STEAMERS "D. E. KNIGHT," "SILVIA" AND "DAISY."

From Upper River to Sacramento—Wheat and barley	10,433

BOATS OF CALIFORNIA TRANSPORTATION COMPANY.

From Lower Sacramento to San Francisco—Fruit produce		46,419
Total Sacramento to San Francisco		365,512
Passengers	11,600	
From landing on Feather River to Nevada Warehouse, Vallejo and San Francisco		10,497
Fruit and other merchandise from Marysville and various landings on Feather River to San Francisco		1,928
Merchandise carried from San Francisco to Marysville		8,057
		20,482

The above statements are not to be relied upon as showing the actual river tonnage. It is in excess of the actual tonnage, as a large percentage of it is in duplicate — that is: has been counted twice, owing to transhipment of freight from lower river boats to upper river boats.*

The passenger and freight movement over the lines west of El Paso, controlled by the Southern Pacific system (for the first quarter of the year reported by the C. P. R. R. Co., and for the last three quarters by the S. P. Co.), as compared with 1884, was as follows:

	Pounds, 1884.	Pounds, 1885.
Local Freight	3,984,262,650	3,879,882,500
Through Freight	722,047,680	756,841,950
Company Freight	1,030,510,710	854,830,120
Total	5,736,821,040	5,491,554,570
Passengers.		
Through, Eastward Bound	37,559	37,293
Through, Westward Bound	58,428	59,772
Local	2,225,979	2,123,137
Ferry	6,451,887	6,574,939
Total	8,773,853	8,795,141

* The following is a statement of the wheat transportation of the Sacramento River from July 1st, 1886, to Jan. 1st, 1887 ..... 51,879 tons
Shipped in January, 1887 ..... 3,400 "
Remaining in warehouses Feb. 1st, 1887 ..... 7,464 "

Total for crop of 1886 ..... 62,743 tons

The above includes all points north of Sacramento.

STATEMENT SHOWING THE SOURCES OF GROSS EARNINGS AND OPERATING EXPENSES ON THE RESPECTIVE PROPERTIES FROM THE COMMENCEMENT OF OPERATIONS TO DECEMBER 31, 1885.*

Name of Line.	Miles of road Operated.	Date of Commencement of Operations.	Freight.	Passengers.	Baggage.	Express.	Mail.	Miscellaneous.	Total Receipts.	Operating Expenses.
I. Central Pac. R. R. & leased Lines.										
Central Pacific Railroad & B. Branch	1,252 44	April 1, 1885	$5,086,857.51	$2,657,244.52	$23,183.05	$136,374.94	$266,668.82	$252,442.22	$8,422,771.06	$3,608,563.43
California Pacific Railroad	115.44	"	533,021.30	354,658.49	2,174.45	11,112.47	15,126.12	16,306.25	932,399.08	386,861.50
Northern Railway	153.63	"	764,806.93	568,445.23	3,488.55	21,419.09	17,951.67	19,189.79	1,395,301.26	506,263.70
San Pedro & Tulare Railroad	46.51	"	335,602.94	129,534.48	1,189.99	10,243.65	5,980.05	5,569.27	488,180.38	151,815.54
Sacramento & Placerville Railroad	5.64	"	11,997.88	9,909.28	49.19	314.61	481.05	110.33	22,772.34	9,025.58
Stockton & Copperopolis Railroad	49.00	"	50,184.61	22,602.25	25.26	900.26	2,195.55	908.81	76,816.74	43,753.09
Amador Branch	27.20	"	20,283.53	8,856.18	46.04	540.00	1,372.23	144.87	31,242.85	15,275.20
Total	1,649.86		$6,802,664.70	$3,751,310.43	$30,156.53	$180,905.02	$309,775.49	$294,671.54	$11,369,483.71	$4,721,557.84
II. Southern Pac. R. R. & Leased Prop.										
S. P. of Cal. Northern Division	201.21	Mar. 1, 1885	$ 506,540.40	$ 523,932.18		$15,466.07	$11,309.80	$39,992.78	$1,096,841.23	$599,504.58
S. P. of Cal. Southern Division	553.36	"	1,682,438.22	761,811.94	$9,921.56	45,671.88	52,071.89	57,705.06	2,609,621.55	1,434,066.36
S. P. of Arizona	383.74	"	776,862.88	346,159.58	5,096.50	21,265.55	44,038.50	95,400.75	1,288,823.76	580,634.30
S. P. of New Mexico	171.06	"	354,851.62	150,052.26	1,777.82	8,596.83	12,697.00	45,686.56	573,662.09	233,291.29
Los Angelss & San Diego R. R.	27.60	"	35,741.66	23,634.55	158.93	1,000.00	2,384.70	467.61	68,387.45	36,077.41
Los Angeles & Independence R. R.	16.83	"	45,538.12	31,043.19	12.23	300.00	694.60	455.95	37,044.19	19,829.00
Total			$3,360,972.90	$1,841,633.70	$16,967.14	$92,300.33	$123,196.49	$239,708.71	$5,674,380.27	$2,903,402.94
Sacramento River Steamers	1,354.80	April 1,1885							$110,984.11	101,908.26
Total Pacific System			10,163,238.60	$5,592,944.13	$47,123.67	$273,205.35	$432,971.98	$645,364.36	$17,154,848.09	$7,726,869.04

* See Poor's Manual of Railroads, 1886, p. 934–936.

A comparison of these statements appears to indicate that the Sacramento river as a navigable highway is of very little importance. But it must be borne in mind that this is not the real standard of the value of this river as a navigable highway. Its very existence is what assists in controlling the rates of travel and transportation, and that fact alone shows the necessity of its preservation.

A resumé made by Mr. Petit, concerning the three great trade routes in France, and published in the *Bulletin des Travaux Publics,* 1881, shows the following interesting comparison:

Transit.	Length.		Tonnage.		Proportion of Tonnage
	Kilometers.	Miles.	Mean.	Kilometers.	Kilometers.
Railways	24,383	(15,141)	415,394	10,801,259,457	75
Navigable rivers.	11,986	(7,432)	182,000	2,174,531,000	15
Highways.....	37,462	(23,264)	39,400	1,480,148,000	10
Total.....	73,831	(45,827)	196,000	14,455,938,457	100

Sir Charles A. Hartley, in a lecture delivered before the Institution of Civil Engineers, very significantly remarks that railways will prosper where water communications languish, when the latter labor under great physical difficulties. That since the establishment of railways in England, the construction of canals and the improvement and canalization of rivers have ceased to be appreciable. Such, however, is not the case on the continent.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME IV.—MARCH, 1887.)

MINING DEBRIS IN CALIFORNIA RIVERS.

[CONTINUED.]

BY AUG. J. BOWIE, JR., MEM. TECH. SOC.

Read March 4, 1887.

Can mining be successfully prosecuted and harmonize with those interests with which it is apparently brought into conflict?

To solve this problem satisfactorily, there must be full information on the following points:

1st. There must be accurate and detailed surveys of the whole field, including the sources of water supply and the discharges of all streams and tributaries, with their flow and geological actions.

2d. Examinations showing the amount of detritus now discharged, and which will probably be discharged, into the streams from the mines and other sources.

3d. Full information as to the sites for barriers and reservoirs; the character of barrier required to be built, and their construction.

4th. How land is be obtained for these requirements, and what legislative action is necessary to this end.

5th. Estimates of the cost of erecting and maintaining the works necessary to impound the detritus.

A review of the situation shows that though there have been no complete detailed surveys of the entire field, what may be properly termed a reconnaisance of the whole section of the country has been made by the Federal and State Governments, supplemented by surveys, more or less in detail, of strategic points. The available supply of water from the various catchment areas is but partially known, and it can be safely stated that there exists only general information concerning the discharge of the tributary streams, with their grades and cross-sections.

From the surveys and geological explorations of the Upper Sacramento River, the fact is established that this stream has continued to occupy its present channel, which, in many places, is more than a mile in width, during the more recent geological periods. No tributaries entered it except from the west side, and these have always been and still are charged with large amounts of very heavy gravel and detritus; whereas from the Sierra Nevada side to the north of what is now known as Feather River, the Sacramento received only the ordinary drainage of the country, and was entered by no streams. At this period the country below was entirely submerged, and it is shown by the regimen of the Upper River that all the material which was discharged from it immediately commenced land building in the large interior basin which received its waters. That this operation resulted in the formation of the Sacramento Valley is corroborated by the fact that the channel of the river in this region is elevated from ten to twenty-five feet above the country through which it flows, the land on either side of it receding for miles, along its entire length, until the stream discharges into the bays.

It is therefore evident that all that portion of the Sacramento Valley to the north of Feather River, lying below the level of the present river channel, for a length of sixty-five miles, is clearly the result of natural erosion and denudation of this upper section of the country; while below this point the land building has been assisted by the discharge of debris from the

Sierra Nevada on the east through the agencies of the Feather and American rivers.

There has also been denudation from the Sierra, the Marysville Buttes, and the Coast Range during earlier periods. These actions are not visible in recent deposits, but for miles back of the banks of the Sacramento its influence has been the controlling element.

The geological explorations conducted by Prof. Whitney show that the channels of the Pliocene rivers which flowed into the Sacramento from the Sierra Nevada side, have been eroded to a depth of from several hundred to two thousand feet or more, and the material from the detrital accumulations of the Pliocene epoch have been discharged into the river below, and deposited over its alluvial basins. These facts therefore clearly demonstrate what agencies have assisted in the building of this lower country, and that from natural causes, without any assistance from mining or agriculture, the country, from its very topography, has been and must be forever subject to overflow and damage from debris.

The inadequacy of the water-ways of the streams tributary to and including the Sacramento River, to discharge during flood periods the water draining into the Sacramento Valley, has already been referred to on page 5 of this paper. Of the 4,769 square miles in the Sacramento Valley proper, the river, slough and channel surface of perennial streams is only 38.05 square miles, with a very limited fall, whereas the drainage basin of the Sacramento River aggregates 26,187 square miles.* It is, therefore, evident that in this section of the State, where there is a mean annual precipitation of from 30 to 40 inches of rain and snow, whenever the rains are excessive, as in 1861 and '62, or when warm weather sets in after heavy snows, floods will invariably occur, and 1,700 square miles of the 4,769 square miles of the Sacramento Valley will be subject to overflow.

The topography of this country favors it, and this condition of affairs will continue, mining or no mining, farming or no farming, river improvement or no river improvement, as long as

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* See Physical Data and Statistics of California, by W. H. Hall, State Engineer, p. 394.

the difference in elevation between the mountains and the valleys exists, and until erosion ceases.

The topographical features of the country having been outlined in their relations to the mining counties, and the requirements having also been stated for the solution of the question under consideration, it is evident, that to deal fully with its varying conditions in the different parts of the State, would be impossible in a paper of this scope. The regions tributary to the Feather and Yuba rivers, as the best known, may be considered as typical, and will therefore be described somewhat in detail, and remedial measures will be outlined, showing how the debris in this portion of the State can be impounded.

It is in these regions, particularly on the Yuba, that gravel mining has been prosecuted on a larger scale than in any other part of the world, and should the mines be worked in the future, it is from here that the largest (sectional) contributions of mining debris may be expected. Moreover, in this part of the State the greatest amount of capital is invested, and the most extensive mining works have been executed. These gold-bearing deposits, among the richest in California, have been the most productive in precious metal, and from them the principal future gold produce of the State is to be extracted whenever the mining interests are relieved of the existing restraints. Into this drainage area, also flow the tailings from the productive gold quartz mines, which have with the gravel mines made California famous, and enabled the United States Government to resume specie payment and to be in a position to pay off the national debt in gold.

Taking isolated cases, it is an easy matter to devise a plan by which a claim can work and impound its debris; but the object in view is a general plan on the most economical principles, which would permit the various mines or line of claims draining or discharging into the streams, to jointly work without interfering with one another, and at the same time carry on mining operations without detriment to the agricultural interests or navigation of the rivers below.

Such a work, to be of permanent value, must from the extent of the mining operations, necessarily be on a scale which is com-

mensurate with the magnitude of the requirements. No single work will probably be called upon to meet the necessities of the case, but a system of works would possibly be found ultimately to be the grand desideratum. How it is to be constructed and maintained, will depend upon the plan or system adopted; but whatever system be adopted, the structures should be built with reference to permanency, and to act not only as barriers to any inroads from mining debris, but as guards and protectors from those great and more powerful agents and continual destroyers—Nature and Time.

From official documents it is seen that the Feather River with its tributaries has, with the exception of the San Joaquin and Sacramento rivers, the largest drainage area of any single river in the State, aggregating at Oroville 3,654 square miles on the western slope of the Sierra Nevada. It embraces all of Plumas, and portions of Sierra, Shasta, Lassen and Butte counties. The elevation of this area varies from 150 feet to 12,000 feet above sea level. Pine, fir, and oak trees are found over the greater portion of this area.

The formation of the country, consisting principally of lava, slate, and granite, is covered with soil resulting from the disintegration of these materials. Large valleys and meadows, frequently swampy, valuable as pasturage lands, are found at high elevations above the limits of hydraulic mining.

Feather River has five forks, known as the North, Middle and South forks, and the East and West branches of the North Fork. Their relative positions are shown on the map. In June and July, 1881, these streams were gauged,* and their discharge was as follows:

West Branch.....	150 to	200	cubic	feet	per	second.
North Fork.....	1,000 to	1,200	"	"	"	"
Middle Fork.....	600 to	700	"	"	"	"
South Fork.....	100 to	125	"	"	"	"
Total.....	1,850 to	2,225	"	"	"	"

It is stated that at extremely low water these streams discharge from 25 to 35 per cent. less than given above. The

*See House of Rep. 47th Congress, 1st Session, Ex. Doc. No. 98, p. 79.

mean winter discharge is placed, however, at 5,000 to 10,000 cubic feet per second; the flood discharge ranging from 50,000 to 70,000 feet per second.

The annexed table shows approximately the grades of the various forks:

*North Fork and Main Stream.**

From—	To—	Distance in miles.	Fall per mile, in feet.	Rise of floods above low-water.	Remarks.
Bidwell's Bridge...	Carriboo.....	15	115	8	Two falls between.
Carriboo.....	Mouth East Branch.	6	65	10	
East Branch.....	Chip's Creek	3	63	30	
Chip's Creek.....	Buck's Creek.....	8.5	52	25 to 30	
Buck's Creek.....	Upper end Big Bend	19	46	25 to 30	
Upper end Big Bend	Mouth West Branch	12	36	25 to 30	
West Branch.....	Middle Fork.....	9	50	25 to 30	
Middle Fork.....	Oroville.....	7	14	40	
Oroville	Burt's Ferry.....	12.8	4.26	40 to 22	Report State Engineer, 1880, part II, pp. 32-35.
Burt's Ferry.....	Yuba River.....	24.2	1.46	22 to 25	
Yuba River.....	Nicolaus.....	19.6	1.21	.....	
Nicolaus.....	Sacramento River..	10.4	0.92	.....	
West Branch.					
Nelson Bar.....	Yankee Hill Road..	3	35	20 to 30	
Yankee Hill Road..	Mouth.....	2½	36		
Middle Fork.					
Nelson's Point.....	South Fork.....	45	84	25 to 30	
South Fork,.....	Bidwell's Bar.....	1¾	34		
Bidwell's Bar.....	Mouth..	2	50		
South Fork.					
Stringtown	Mouth.....	3	22	15	

On the West Branch of Feather River there is no hydraulic mining, and the rich bars and gravel deposits have been worked out and abandoned.

The drainage area of the North Fork is larger than the combined areas of the other forks.

*See House of Rep. 47th Congress 1st Session Ex. Doc. No. 98, p. 79.

The limits of hydraulic mining on this stream are from Dutch Hill to Big Bar, a distance of 36 miles. The cañon from Bidwell's Bridge to Oroville, a distance of 80 miles, is from one-half to three-fourths of a mile deep, though in places somewhat less. The bottom width of the cañon may be placed at 100 feet, and rarely exceeds 200 feet, while its sides have a slope of from 25° to 75°.

Swiss Ravine is at present the head of the hydraulic region, receiving the detritus from Dutch Hill. The deposits along the head of the stream, as well as along the stream itself, have been mined out. In this immediate drainage basin there is a large amount of disintegrating lava, forming a light soil spread over large areas, which, where unprotected by vegetation and timber, is readily washed off by the rains. The sides of the granite mountains disintegrate readily, and even during dry weather are continually breaking off and sliding into the streams. There is, therefore, a large natural wash entering this fork, and the flood deposits on the lands below Hamilton's Ferry are largely attributable to this source.

The East Branch, a tributary to the North Fork, is formed by Indian and Spanish creeks. The other tributaries of the North Fork have a low water discharge, which rarely exceeds 75 to 80 cubic feet per second. When the mines are running the total quantity of material discharged from them and draining into the North Fork of the Feather is stated officially to be about 987,500 cubic yards* annually, as shown by annexed table:

Streams.	Mines.	Quantity per year.	Remarks.
		Cubic yards	
Swiss Ravine....	Dutch Hill.....	500,000	Fine material.
East Branch.....	Quincy Group.... } Brooks Halstead.. }	323,000	Maximum quantity, needing storage.
Yellow Creek	Yellow Creek Claim	(1,000,000)	Estimated capacity not yet developed.
Chipp's Creek....	Lotts,.....	140,000	
Flea Valley.....	Big Bar.....	15,000	
	Morris.....	.....	Does not reach Feather River; stored in Morris Lake.
		978,500	
		1,978,500	Including the estimate for Yellow Creek.

* See House of Rep., 47th Congress, 1st Session, Ex. Doc. No. 98, p. 81.

The Quincy group above mentioned are the largest and richest mines, and 80 per cent. of all their debris is deposited in and above the American Valley, in a natural storage reservoir. Spanish creek, above the valley, has a grade of 35 feet per mile, and in it a grade of only 12 feet per mile. No coarse gravel appears ever to have passed through it. The material coming from the other mines can be readily stored on the East branch by constructing a barrier between Rich Bar and Twelve Mile Bar, where the cañon is only 100 feet wide at the bottom, the sides sloping at an angle of from 35° to 40°. An abundant supply of material can be obtained from the mountain sides.

There is another site for a barrier at the mouth of Grizzly Creek, should a reservoir be needed. The annexed table gives further details of the mines on the East branch.

*Quincy Group and Mines on the East Branch.**

No.	Name.	Condition.	Water used yearly miner's inches.	Material discharged, Total yearly.	Material discharged, Estimated amount reaching the North Fork.
	Quincy Group:				
1	Fails Hill	Not worked			
2	Mountain House	do			
3	Bean Hill	do			
4	Cadwalader Hill	do			
5	Gopher Hill		100,000	4356,00	87,120
6	Badger Hill	Not worked			
7	Hungarian Hill		57,200	289,000	57,800
8	East Fork Mining Co.		12,000	48,000	48,000
9	Hardsock	Not worked			
10	Halstead		16,000	48,000	48,000
11	Brooks		38,400	110,000	50,000
12	Keeps		20,000 to 30,000	27,000	27,000
13	Laguire		1,400	5,600	5,600
	Total			903,200	323,520

On the Middle and South Forks, hydraulic mining is very limited, and their cañons, compared with the Yuba, Bear and American rivers, contain no detritus of any importance.

* See House of Rep., 47th Congress, 1st Session, Ex. Doc. No. 98, p. 81.

There are a few drift and quartz mines, but these have been idle for years. The old mines at Bidwell's Bar and Stringtown are worked out and the river bed is here filled with boulders and cobbles which have found a permanent resting place.

From two miles above Oroville to Burt's Ferry the United States map of the Feather River shows that on this reach there is an average fill of from 10 to 12 feet over the area covered by the low water channel of the stream, and that a large portion of the town of Oroville is below the flood plane. That there is no place for storage of detritus from any of the mines in this locality, is a fact established by the official surveys.

The need of restraining barriers and measures to decrease the denudations from the Feather River Basin have been pointed out in Ex. Doc. No. 98, page 84, House of Representatives, 47th Congress, 1st Session. This river is in the preliminary stages of a permanent change of channel — namely, from Hamilton's Ferry to Butte Slough, or across the North Butte Basin. Unless remedial measures are undertaken this change may be expected in the near future.

Above the Oroville group, mining is carried on to a very limited extent, and it may be said that little or no hydraulic mining is being prosecuted on the Upper Feather.

The Yuba River, rising in the western slope of the Sierra Nevada, is a tributary of the Feather, which it enters at Marysville, 30 miles above its mouth. The extreme length of its water shed is about 60 miles, and its extreme width about 36 miles, with a drainage area estimated at 1,298 square miles.

The Yuba* ranks as the fourth river in size in the Sacramento Valley.

Extreme low water discharge..... ...	500 cu. ft. per sec.
Mean winter discharge..... about	1,500 " " " "
Flood discharge.....	26,000 " " " "

Its drainage basin is divided into five smaller ones, designated as North, Middle and South Forks, Deer and Dry creeks. The first mentioned is the largest and has the greatest elevation. The water from all the various basins unites in the foothills with

* See Annual Report of Chief of Engineers for 1882, Appendix MM., p. 2611.

the exception of Dry Creek, which joins the main stream at a point 12.75 miles above its mouth.

The elevation of the Yuba Basin is from 200 to 8,000 feet above tide water. The precipitation is thought to be not so great as upon the Feather River water shed.

The amount of detritus which has heretofore been discharged from the North Fork and its tributaries is annually diminishing. The various deposits in this stream are gradually being washed away and the channels deepening. In fact, hydraulic mining in this basin, owing to the exhaustion of the deposits, is rapidly declining, and the presence of lava in great quantities has compelled many of the miners to resort to drifting.

The following mines are still worked in this section of the country:

Foss & Co.		Eureka,	Sierra	Co.
Wigginsville		"	"	"
W. A. Morse & Co.		"	"	"
Pioneer		Slate Creek	"	"
Morgan & Donahue	St. Louis	"	"	"
Poverty Mill Mining Co.		"	"	"
Niagara Hydraulic Mining Co.	Hepsidam,	"	"	"
Last Chance Mining Co.	Howland Flat,	"	"	"
Nevada Hydraulic " "	Gibsonville,	"	"	"
Sears' Union " "	Howland Flat,	"	"	"
Gibsonville Union " "		"	"	"
Gold Gravel Hydraulic Min. Co.,	La Porte,	"	"	Plumas "
Baird & Co.	Fir Cap,	"	"	Sierra "
Gold Valley Hyd. M. Co.	Poverty Hill, Rattlesnake Ravine,	"	"	
Liberty & Co.	Portwine, Slate Creek,	"	"	

The greater portion of the debris entering the North Fork comes from Slate, Cañon and Goodyear's creeks. The first mentioned stream receives the material from the mines at La Porte, Gibsonville, Howland Flat, Poverty Hill, Portwine, and Barnard's. The second, from Eureka North, Craig's Flat, Morristown, Scale's Diggings, and Poker Flat, while Monte Cristo and Chapparal Hill discharge into Goodyear's Creek.

The tributaries to the several creeks which receive a greater portion of the debris entering the North Fork, are:

Slate Creek	Rabbit Creek. Rattlesnake Ravine. Small Gulches.
Cañon Creek	Little Cañon Creek. Scales' Cañon.
Goodyear's Creek	Various small ravines.

The several districts mentioned, and all the tributaries to and cluding the North Fork, were estimated in 1881 to have discharged into the Middle Fork of the Yuba for that year $3\frac{1}{4}$ million cubic yards of detritus.

From the meagre data which exist, this estimate is probably conjectural.

The grade of the cañon of the North Fork for 35 miles above its junction with the Middle Fork is from 70 to 90 feet per mile, with reaches on bars of less grade. Its average width is 125 feet, with an extreme width of 300 feet at Bullard's, Foster's and Goodyear's bars, for a short distance, and a minimum of 80 feet. The sides of the cañon (which has a depth of $\frac{1}{4}$ to $\frac{1}{3}$ of a mile and runs through belts of slate and serpentine) have a general slope approximating 30° to 35°. Several million cubic yards of detritus are estimated to have lodged temporarily along this cañon, and are gradually being washed further down.

The initial point of the survey of the Middle Fork of the Yuba commences at Moore's Flat Bridge, where the pack-trail crosses from Moore's Flat to Minnesota Hill. Above this point, which is 18 miles in an air line from the summit of the Sierra Nevada, there is little or no hydraulic mining, though gold-bearing alluvions occur some 5 miles further up on the Sierra County side. The cañon below Moore's Flat Bridge is cut through a slate formation partially disintegrated, its sides, which are covered with brush, sloping at an angle of 35°. The bed of the stream is about 100 feet in width.* There are here marks of tailings coming from a small ravine which enters from the left bank; and about 350

* The elevation at low water above mean low tide in the bay is 2,884 feet. For full details of the surveys of the middle and south forks of the Yuba, see Appendices A and B, Part III, State Engineer's Report 1880, from which this description is taken.

yards lower down, there is an old and extensive deposit similar in character to the dumps upon the South Fork, except that here the sand and gravel appear whiter. (See Plate VI.)

For the succeeding 7,900 feet, there is some change in the character of the river bed, the stream averaging 125 feet in width. The low water channel shifts from side to side over low bars of cobble stones of which there are many in the bed of the stream. At the end of this reach, a small ravine enters the river from the left bank, above which point about 73,000 cubic yards of detritus are stored, while below it is a similar deposit about 20 feet in depth at the mouth, 800 feet in length, and 500 feet in width, aggregating a total deposit of 30,000 cubic yards.

A short distance furtber down there is another ravine, and through this is discharged the debris from Woolsey Flat mines, in which fine material largely predominates. The dump is 1,000 feet long, 300 feet wide, and about 20 feet deep, 75 per cent. of it being liable to removal by floods.

For the succeeding thirteen miles the cañon is about 300 feet wide, one-half to two-thirds of its water-way being filled up with low bars of cobble stones. Its sides are rough, and there is a heavy growth of trees on the left bank, the right being comparatively bare, and it is estimated that 259,800 cubic yards of detritus are here lodged.

From hereon down to the San Juan Dam, .71 miles, the cañon is rough and precipitous, its sides and bottom being composed of coarse granite.

From San Juan Dam to Freeman's Bridge, 15.32 miles, the cañon is exceedingly rough and winding. Numerous small tributaries enter the river between these places, the principal being Bloody Run and Grizzly Creek. Immediately below the mouth of the latter, through which the Cherokee mines formerly discharged (5.04 miles below Freeman's Bridge), is the dump of the Columbia Hill mines, filling the entire bed of the river, and forming an obstruction similar to that at Sailor's Flat and Blue Tent dumps. At the mouth of the creek, 31 feet above the water in the river, there are marks of deposits which slope gradually to the present river bed, intersecting it at a distance of 1,200 feet below the mouth of the creek. Below these dumps the deposits are coarser and more extensive than above.

Some two miles above Freeman's Bridge is Emory's Flat, 2,500 feet long, and 700 feet wide. Its general elevation is about fifteen feet above low water. The mountains slope back at angles of from 24° to 30° from the flat, which is entered on either side by low ravines.

The cañon below Emory forms a narrow gorge, across which an obstruction could readily be thrown, and this entire space used for storage purposes.

From this point down, the cañon continues steep and narrow to the mouth of Oregon Creek, which empties 2,100 feet above Freeman's Bridge. For 4,100 feet above to 4,700 feet below Freeman's Bridge, the bed is from 200 feet to 600 feet wide, and its grade 60.4 feet per mile.* A storage reservoir might here be made by placing a debris barrier at the narrow part of the cañon, 4,700 feet below the bridge.

From Freeman's Bridge to the junction of the Middle and North forks, 4.18 miles, the cañon is rough and precipitous. The only debris here lodged is at the American dump, the tailings entering from the left bank, .64 miles above the mouth of the Middle Fork. The cañon, which has a width of from 100 feet to 150 feet, shows marks of heavy deposits, which have been swept out by flood-waters, and along its bottom are strewn huge masses of stone.

The North and Middle Forks, forming the main forks, come together 4.18 miles below Freeman's Bridge, thence flowing through a cañon from 1,200 to 1,500 feet deep, and from 100 feet to 125 feet wide. The roughest part of this cañon, where it is very precipitous, and almost inapproachable, is about four and one-half miles in length. Drift-wood indicates that the waters have risen to points at least 40 feet above the bed; but no debris is deposited in this cañon.

The tailings from the Manzanita Hill mine enter the Main Fork 1.19 miles below the mouth of the North Fork, and here but little debris remains.

At Missouri Bar, the cañon is from 250 feet to 300 feet wide, with reaches of 500 or 600 feet. There are narrow gravelly benches on either side, slightly elevated above low water. The

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*The elevation at low water at the bridge above mean low tide in the Bay is 1,698 feet.

mountains recede, giving the sides of the gorge much flatter slopes as far down as the junction of the Main and South forks, a distance of about three miles. The debris along this section is estimated at 30 feet in depth at the lower end, decreasing to nothing at the upper end.

Between the lower end of the cañon and the mouth of the South Fork, three small streams enter from the north. Two of these have flat side slopes, light grades, and low flats on either side of their channels, extending some distance back from the river showing them to be good places for the storage of debris. The grade of the stream is about 30 feet per mile, and its bed is filled at the upper end for about three-fourths of a mile with large cobbles, which decrease in size to coarse gravel at the mouth of the South Fork.

The South Fork of the Yuba has a drainage area of 306 square miles, with elevations from 400 to 8,000 feet above sea level. The average fall of the cañons to an elevation of 2,660 feet above sea level is 56.35 feet per mile.

Above Omega Creek, there is no hydraulic mining. Below it, some three-fourths of a mile, the cañon widens in places to 1,500 feet. Its average grade is 54 feet per mile for the whole cañon to Washington, 2,800 feet. The cañon below Washington for the first $1\frac{1}{4}$ miles, narrows with precipitous sides, the grade ranging from 55 to 59 feet per mile. A mile and a quarter further down stream, the cañon is very narrow and steep, and for a half a mile in length, has a width of about 100 feet, with a grade of $41\frac{1}{2}$ feet per mile. Flood waters at this point sometimes rise 25 feet above the low water stage of the river. From here on, the cañon widens, and the grade is gentler. Nine miles further down, the grade averages 35 feet per mile.

Humbug Creek enters the South Yuba $20\frac{4}{10}$ miles above its mouth. The channel at low water, which formerly measured 100 feet across, is now 350 feet wide.

From Humbug Creek to Sailors Flat Dump, 2.54 miles, the cañon has a grade varying from 44 to 66 feet per mile, with one reach of 25 feet per mile, and from Sailors Flat to Edwards' Bridge, 1.55 miles, the width of the channel is 150 feet, filled to

a depth of from 5 to 20 feet with debris, the grade being 55 feet per mile.

Edwards Bridge is 16½ miles above the mouth of the South Yuba River. The floor of the bridge is 1,990.6 feet above tide water level. Low water level of 1879 was 1,954.7 feet, and flood water mark of 1862 was 1,973½ feet above the plane of low tide.

From Edwards' Bridge to Purdon's Bridge, 4.05 miles, the grade is from 51 to 71.02 feet per mile. Large deposits exist all along the cañon until the outlet from Columbia Hill is reached, where the cañon is only about 100 feet wide, and marks of old deposits are seen at points 20 feet high.

From Purdon's Bridge to Jones' Bar, the cañon is narrow and steep for its entire distance, with a grade of from 80 to 106 feet per mile, and in places 134 feet.

Below Jones' Bar, the cañon for about a mile is from 500 to 600 feet in width with a grade of 60 feet per mile. A small amount of debris remains lodged in this portion of the cañon.

Below this long cañon, the tops of the mountains are further apart and the slopes flatter. There is a reach one mile long, with a channel grade of 57 feet per mile, along which over 200,000 cubic yards of debris are lodged. A barrier could be readily constructed at this point, which would convert this place into a good storage reservoir for tailings.

From Jones' Bar to the mouth of the South Fork, a distance of 6.27 miles, the cañon is somewhat wider than above the Bar, the grade ranging from 53 to 124 feet per mile. Along this stretch, several small streams enter the Yuba, the principal one by which it is joined some 5.9 miles above its mouth being Shady Creek.

Below Bridgeport, on the main stream, there is a good site for the location of a debris barrier. The cañon narrows to a width of 125 feet below the junction, and there is an abundance of material available for the construction of such work. This structure could be readily carried to a height of 250 feet, and with the flats above it, an immense quantity of debris could be stored. When filled to its crest, the water could be turned across a narrow neck of rocky land and again dropped into the Yuba some considerable distance below the barrier.

From the mouth of the South Fork to the Yuba Mill and Mining Company's shaft, the distance is 13.6 miles. The bed of the river for this entire distance is filled with detritus from one side of the mountain to the other. Over this debris the present stream flows on a regular and even grade. The sides of the cañons slope at low angles, and bluffs now and then close in upon the river. The reported depths of the deposit are given by Mr. Manson, C. E., in his report to the State Engineer, as follows:

At the mouth of the South Fork.....30 feet to 40 feet.
Three miles above Deer Creek.....40 feet.
At the mouth of Deer Creek.....80 feet.
At the Smartsville dumps.....125 feet.
At the mouth of Timbuctoo Ravine.....80 feet.
At the Yuba Mill & Mining Co.'s shaft...75 feet to 80 feet.

The cañon, as far as Timbuctoo Ravine, averages from 300 to 400 feet in width, ranging from 125 to 550 feet. Below this point its width increases to 1,000 feet in the widest places.

The greatest portion of the deposit in this division of the river consists of fine quartz, gravel and sand; only about 15 per cent. of the total amount at the mouth of the South Yuba being estimated as cobble-stones, which disappear about a mile above the Smartsville dump. Upon and below these dumps, however, for the remaining distance to the Yuba Mill and Mining Company's shaft, they form a large part of the deposit.

Deer Creek discharges into the Yuba on the left bank at a point 7.57 miles below the South Fork.* The general grade of the stream in this division is quite uniform, being from 22 to 23 feet per mile, and with its increased width a favorable opportunity is here offered to retain the debris brought down from the mines.

At the Narrows, about one mile north of Smartsville, the river is about 300 feet wide, the sides of hard blue trap, sloping at an angle of from 50° to 32° for an elevation of upwards of 200 feet above the bed of the river. Above this height the mount-

* For details of distances, grades and elevations, see State Engineer's Report, Part III, 1880, p. 63.

ains, to an elevation of 1,000 feet or more, have a steep slope. In the vicinity of the Narrows there is an abundance of suitable material for barriers, which can be readily obtained and placed in the bed of the river wherever needed. Official surveys show that there is large storage room, for debris and detritus in the bed of the river above this point, which averages 300 feet in width and has a length of 44,500 feet, the sides of the mountains sloping at angles ranging from 30° to 35°.

From the Yuba Mill to the mouth of the Yuba, the distance is 15 miles. Below the Yuba Mill and Mining Company's shaft, for a distance of eight miles, the river has a width between the levees of 2.8 miles. It then contracts irregularly in width, and during periods of flood discharges into the Feather with a width of from 1 to 1½ miles. Over the greater portion of the fifteen miles referred to, there is deposited a large amount of sand, containing some coarse gravel in the upper portions, whilst in the lower part it consists largely of deposits of fine clay.

Four and a-half miles below the Yuba Mill is Point de Guerre, which is a rocky point some 40 or 50 feet high, and where the river narrows to about one mile. Opposite to this place there are slopes rising to a height of 100 or 150 feet above the bed of the river. A barrier could be erected in this narrow portion of the stream, which would retain a large amount of the mining debris. Below this point the high lands gradually merge into the plains.

The mining districts draining into the Bear and American rivers are described in the official reports, which show in detail the condition of affairs on those streams.

As there are no data of the denudation and erosion in the mountains and valleys of this Coast due to natural causes, the annual contribution from these sources can only be approximated by analogy.

The Sierra Nevada Range, which borders the great valley of California on the east, has an average elevation of about 8,000 feet, with peaks varying in height from 10,000 to nearly 15,000 feet. On the sides of these mountains, which have a descent of a most precipitous character, are immense tracts of denuded land covered with disintegrated lava, detritus, and metamor-

phosed schists. The temperature over this area, where the mean rain and snow-fall exceeds fifty inches, varies from extreme heat to extreme cold.

It is therefore evident that the geological formation of this range, its topographical features and climatic influences, are such as to render denudation both rapid and destructive. What is true of the Sierra Nevada is also true to a certain extent of the mountains which border the Great Valley to the West, and comparing this region with the valley of the Po, any one familiar with both valleys will undoubtedly say that the denudation and erosion per unit of area is greater in California.

ESTIMATED ANNUAL DISCHARGE OF DEBRIS AND DETRITUS FROM THE MINES, ETC.

On pages 14 and 15 of this paper are given the official reports of the amounts of the debris discharged from the mines into the various streams tributary to the Sacramento and other rivers. Since those reports were made, many changes have taken place in the mining regions. On page 16 an estimate is given of the total amount of material which would probably be discharged into the Yuba River Basin proper, based on the total number of inches of water there available for mining purposes.

Names of Mines.	Miners' 24-hour inches.	Cubic yards per inch.	Total amount of gravel moved.
North Bloomfield	800,000	.....	.....
Milton Co	500,000	.....	.....
Omega	150,000	.....	.....
Connelly & Gowell	100,000	3½	.....
Sailor Flat	250,000	.....	.....
Blue Tent	250,000	.....	.....
Eureka Lake	700,000	.....	.....
South Yuba	450,000	.....	.....
Smaller claims	50,000	.....	.....
	3,250,000	.....	11,375,000

These figures are the most reliable obtainable, as they give the absolute amount of water stored and run by the several companies therein named. An additional amount is also included as coming from the smaller companies, which may in rainy sea-

sons obtain water from the drainage of the several little creeks and cañons. The quantity of material moved is approximated at 3½ yards per 24 hour inch of water, which it is believed as a whole, will be found correct, or, if anything, in excess of the actual amount washed. We have, therefore, here a basis to work on, and from which the storage requirements may be figured for the Yuba basin.

SITES FOR DEBRIS BARRIERS.

In describing the regions of the Feather and Yuba rivers, several places have been mentioned where debris barriers could be erected at comparatively small costs. Other sites might have been named, but it has not been considered necessary to enter into such detail until a definite plan for restraining the debris is adopted. There are many ways of controlling the tailings from the mines, and storing them in the cañons along the lines of the streams, where use can be made of all that nature has placed at our disposal. Each particular case will permit of treatment by itself.

As the region of the Yuba has been described more in detail in this paper, attention will be called especially to the sites for debris barriers along that stream and its tributaries.

The surveys of the North Fork of the Yuba show that the cañons are very steep, and that although there are numerous sites for debris barriers and reservoirs, with material in abundance which can be cheaply obtained, it is not considered that the detritus can here be stored as economically as it can be further down on the main stream. Moreover, hydraulic mining on this branch is on the decline, the towns being dependent chiefly on drift, quartz and river-bed mining.

On the tributaries of the North Fork, there are places where storage reservoirs and debris barriers can be readily constructed. Especially might be maintained a site for reservoir and restraining wall on Slate Creek (at a point near the crossing of the Forbestown and Scales diggings road), where the creek is only 80 feet wide, the mountains sloping on an angle of 30° to a height of fully 200 feet and the bed of the stream is from 100 to

120 feet wide, graded back nearly five miles. The chief difficulty to be encountered in the tributaries as well as in the North Fork, are the heavy grades, and the necessity of condemning mines in the beds of the streams.

On the Middle Fork of the Yuba, Emory's Flat (2,500 feet long by 700 feet wide, with the mountains sloping at 24° and 30°) is an excellent place for a reservoir, and in the cañon, a short distance below the flat, a debris barrier can be readily constructed. At a point about 4,700 feet below Freeman's Bridge a restraining wall can be constructed, which will convert a large quantity of the country back of it into a reservoir. Near the mouth of the South Fork there is also an excellent site for the storage of debris. (See page 4 and Plate V.)

On the South Fork of the Yuba there are several sites for reservoirs and restraining walls. Notably may be mentioned the cañon for a mile below Jones' Bar, which is from 500 to 600 feet wide, and below Bridgeport, where the cañon is only 128 feet wide, with abundance of stone at hand, a debris barrier could be cheaply constructed which would convert a large area back of it into an excellent reservoir.

Below the discharge of Deer Creek into the Yuba there is also another site where the detrital wash might be impounded.

Further down is the narrows which has already been referred to and described on page —, and the same may also be said of Point de Guerre, situated 4½ miles below the Yuba Mill.

DEBRIS BARRIERS.

Debris barrier, is a term applied to any structure or obstruction used for the purpose of retaining or assisting in the retention of debris and detritus coming from either natural or artificial causes.

In some instances lines of brush-work, in others, wooden cribs filled or not filled with rocks, may serve this purpose; but where necessary, structures may be erected of masonry or rubble-stone, bonded or not, as circumstances require.

The object of such barriers is not to impound water, but simply to permit and assist in the storage of sand and detritus

behind them, thus forming what, in a certain sense, may be termed retaining walls. In most cases they sustain little hydrostatic pressure, but are frequently called upon to resist the force of water moving at considerable velocity.

In a dam for impounding water, the questions of determining the force to overthrow it and the proportioning of the structure, are capable of exact treatment as the thrust is known in its magnitude, its point of application, and the direction. In almost every part of the world, there are numerous examples of such works having been successfully constructed, and in no one instance have they ever been known to fail except where some fundamental rule of construction had been disregarded. At the present time a dam is being erected for the Croton Water Works, 277 feet high, measured from the bottom of the foundation to the crest of the dam.

As far back as 1871, in the fourteen districts of Madras, it is officially stated that there were 43,000 tanks (reservoirs) of native origin then in use, with approximately 30,000 miles of embankment, and 300,000 separate masonry works. The Viranum tank has an area of 35 square miles, and an embankment 12 miles long, still in operation "after an existence of fabulous duration." The Chembrumbaukum tank, in Chengalpat, has an embankment three miles long, with six waste-ways, having a total width of 676 feet of escape channel. In 1869 there was a dam of earth-work, flanked with masonry, thrown across the Adela Valley. The dam is 7,200 feet long, 72 feet high in the center, with waste-ways at the earth end.*

The material which gradually accumulates in layers behind a debris barrier in time consolidates, and when filled to the crest there is comparatively a small horizontal thrust, the structure simply protecting the face of the deposit from erosion.

It has long since been determined by M. Prony, that when a vertical wall sustains the pressure of a bank of earth, the top of which is horizontal, the maximium horizontal pressure from the backing up of this material is reached when a plane of fracture of the earth bisects the angle which is formed by the earth's

* See East India (Progress and Condition). Ordered by The House of Commons to be Printed 28th April, 1873. P. 60.

sloping back from the foot of the wall on its angle of repose. Therefore the weight of such a prism can be easily calculated. This angle of repose is largely dependent upon the amount of moisture in the material. In theoretical calculations, the backing is supposed to be perfectly dry, and consequently has its greatest pressure, except when the material is in a semi-fluid state. Of course it is always supposed that the barrier will not slide along its base or be overturned around its toe, and that it is sufficiently thick to prevent its bulging.*

Therefore, applying the ordinary formula for the determination of the wedge-shaped prism already described, the pressure which a debris barrier may be called upon to sustain, can readily be determined. By inclining the outer wall inward, the tendency of the stones to slide on one another and bulging are diminished, and by converting the vertical back wall into offsets, there will be a greater resistance to overturning, as the center of gravity is thrown further back from the toe, giving it increased leverage and resistance.

The locations of debris barriers are dependent upon the requirements of the work or the topography of the ground, and at times upon both of these conditions.

The shortest barrier with the smallest height and the greatest storage capacity (all things being equal), is what is most to be desired.

Debris barriers may be placed in the cañons or across the beds of tributary streams or rivers, and even in the plains themselves. Where used in the first mentioned instance, they are simply retaining walls. Where erected along or in the line of running streams, they may be considered either as weirs or restraining walls, partaking under certain conditions to a limited extent of the character of an impounding dam used for the storage of water. When placed across the bed of a stream their purpose is to prevent the erosion of the bed by checking the velocity of the current, and causing the material which it transports to be deposited behind them.

Protection from the flow of detritus, whether from natu-

* See Professional Papers on Indian Engineering, Vol. 1, pp. 326 and 428; also Vol. V, paper No. CLXXIV, p. 50—see Rankine, etc.

ral or artificial causes, can be obtained by the establishment of permanent works, which must be constructed on a scale commensurate with the detrital accumulations. It may not be always practicable to retain all the finer sands and clay which may be held in suspension,* but with the development of any large system of restraining-works along the Yuba, even this can be effected to a great extent — a result due to the reduction in depth of the stream by the increased length of the crests of the barriers as they are raised, which thereby diminishes the suspensory and transporting power of the water, apart from the fact of the great facilities afforded for settling reservoirs, as already indicated in this paper, such places being especially serviceable during low water, when the scouring action is greatest and the stream is very easily controlled.

In the construction of large barriers it is, of course, advisable that their foundations should be on solid ground; but on streams and rivers flowing over beds of detrital accumulations or in alluvial bottoms, this is not always practicable. In India, the foundations of some of the largest weirs constructed across rivers are built on a series of small wells of masonry, sunk to a required depth and then filled in with concrete, rubble or masonry.

A firm foundation may also be obtained by enlarging the bearing surface, or the soil may be consolidated and the foundation extended by a mass of rubble stone. Rock is the best formation to build on, but gravel is also a reliable material for foundations, provided the washing of the sand is prevented; and Vernon Harcourt, in his work on rivers and canals, adds that fine sand and silt do not present insuperable obstacles to a good foundation.

"Prof. Davidson, in writing on this subject as applied to dams in India, says, that if the material of the bed of the stream is

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*The muddiness of the water scarcely requires comment. Daubree has established the fact that the milky tint of the Rhine at Strasburg in the months of July and August, is not due to mud, but to fine angular sand in suspension (grains measuring 1-20 mm.) in diameter; and he likewise proved that sand one-tenth of a millimeter in diameter will float in very feebly agitated water. According to Bischof, the same stream carries annually in solution a sufficient quantity of lime for the formation of 332 thousand millions of oyster shells of ordinary size.

deep sand, gravel or bowlders, no attempt whatever is made to penetrate this in order to prevent sub-surface water passing down stream through the sand or gravel."*

In the construction of large barriers of rip-rap on the Yuba, where the sand has accumulated to any great depth, it might be necessary to prepare a foundation for such a work. The preparation of the sandy bottom would be for the especial purpose of preventing the sand from being washed away from the rocks in the bottom of the structure. This may be accomplished by preparing the bed with fascines, or paving it with small stones, upon which would be placed the rock as received. Where necessary, mattresses of trees or brush may be used to prevent settling; but in the cañons of the Yuba masses of stone can be blasted from the steep side-hills, and an abundant supply of rock and other material is generally everywhere obtainable in close proximity to the barrier sites. If these precautions are taken, and the structure maintained with proper care, every confidence may be felt that no difficulty will ensue from settlement of the work. In corroboration of which may be noted the instances of the dams in India, which are given later on in this paper.

Of course, the larger the rocks the better—the largest being put on the down-stream side, and the smaller ones on the upstream side. The interior of the barrier may be composed of stones of smaller sizes, (which would be unsafe to place on the crest or exposed surfaces), where they would be held in place by the superincumbent weight of the structure. Such a barrier composed of rubble stone relies upon the power of each stone to retain its place, and not upon any bond. The slopes to be given to the barrier depend upon its requirements; and the arrangement of the waste-ways—if such be deemed necessary—is a matter of consideration which must be determined by the engineer in accordance with circumstances and the magnitude of the work.

With barriers of this character, the proposition reduces itself to retaining in position in convenient form a mass of rubble-

* See Ex. Doc. No. 94.—Senate 44th Congress, 1st session.

stone which will cause the river to raise its beds by checking the present velocity of the currents, diminishing its power of erosion and transporting material, thus holding back in the cañons and behind the barriers the detrital accumulations. Should the entire stream pass over the crest of such a barrier, there would result no cataract or Niagara Falls. The outer slope of such a work would be gradual, and opposed to the water would be large blocks of stone that would not be carried away.

The greatest height of floods at the Narrows, where the width is 270 feet, is only 12 feet, increasing the crest of the proposed barrier at this point to 600 feet in width, and the flood depth is immediately reduced over one-half.

The outer toe of a work of this character would really be its vulnerable point, and that can be protected beyond peradventure. There is no question of lack of material.

In the Kaveri river in the Madras Presidency, there is an anicut or dam composed of a solid mass of rough stone 1,080 feet long, 40 to 60 feet broad, 15 to 18 feet high, and stretching across the bed of the stream, which was built over 1,600 years ago.*

In the Krishna delta, at Bezoarah, where the river is 1,300 yards wide, and 6 feet deep at low water, there is an anicut 3,750 feet long and 305 feet wide, composed of stone thrown into the river and allowed to assume its natural slope. Its height is 21 feet above the dry season level of the water. The average flood is 31 feet above ordinary low water, and the highest flood is 38 feet above low water. It is faced with masonry, and has sluices on the flank.†

On the Kalerun River, Sir Arthur Cotton constructed an anicut 750 yards long, divided into three parts by two islands. The bed of the river is composed of sand, and the structure (with 22 sluices), which is made of brick and stone, the foundation 3 feet deep is built on three lines of wells, 6 feet in external diameter each, and six feet deep.

In the introduction of the great system of irrigation in India,

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*See East India (Progress and Condition). Ordered by the House of Commons to be Printed, 28 April, 1873, p. 58.

† See Hydraulic Manual, Part II, p. 71, by Lowis D'A. Jackson, A. I. C. E. Also East India (Progress & Condition) in 1871–22, p. 58.

"Engineers had to discard many of the precepts of the profession. The construction of dams that should fulfill all the conditions demanded, was a difficult problem. Even with so vast a supply of cheap and moderately skilled labor, it was evidently impracticable to carry foundations for the anicuts, weirs, or dams through deep sands to the "bedrock," or to a stratum of clay, etc., and it necessarily involved a contemporary system of levees and of drainage. To raise the waters of a broad stream eight, or ten, or twenty feet above the lowest stages, grave doubts must naturally have suggested themselves upon a proposition to construct a dam across a river bed of loose gravel, of boulders, or of shifting sands of unknown depth, and with an annual flood-rise of ten to thirty feet above the normal low water. For not only was it necessary to view the question as a mere engineering feat, but to look upon it as a commercial enterprise, whether undertaken by the Government or by companies.

Yet this is the problem which has been successfully solved throughout India. It was first accomplished in the Madras Presidency; and although the conditions were in some respects more difficult in Northern India, and engineering opinion divided upon the application, it has nevertheless succeeded."*

Attention has been called judicially to a supposed menace to life and property, in case of a break of one of these debris barriers. It is not possible to conceive how, if the physical condition of things be properly understood, such a catastrophe can be expected to occur. There is certainly no great amount of water impounded.

Any impairment of the integrity of the barrier by reason of floods flowing over it, or by reason of currents undermining it, must be gradual and progressive in character. Sudden and complete destruction—such as sometimes overtakes an earthen dam or reservoir impounding water, entailing destruction of life and property—is not possible in a structure of the kind proposed for debris barriers in the sandy beds of rivers in mining districts.

If the work be undermined, the superincumbent rock will fall

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*See Ex. Doc. No. 94, Senate 44th Congress, 1st Session, p. 11.

into the pit, and protect it from rapid enlargement. The worst that can happen is that a part of the impounded detritus will be carried down stream for a short time until the barrier could be repaired. If, however, it be admitted that, through neglect, the structure might, in a course of years, lose its form by settlement or by being spread out down stream in a long plane of rocks, there can be no disaster comparable to the breach of a dam of a large reservoir of water — such as the failure of the English dam. The impounded material would be free to move under the action of the current, and would be gradually carried down stream. If it were possible for a barrier with detritus impounded to fail by sudden and complete disaster, the increase of the slope of the water surface would, undoubtedly, threaten the banks below with the heaping out of water; but this condition can never obtain, and the displacement of water and detritus in the case of impairment must be gradual in character.

Should a system of barriers be introduced and carried into effect on any of the mining rivers in this State, it is difficult to comprehend even in the event of the destruction of one of them, by artificial means if possible, how the menace to life would occur. To remove all this material, collected and spread to a great width and depth over the bed of the stream above the barrier, the velocity of whose current had been checked and diminished for miles, would be the work of years; and so far as the stream itself is concerned, it is very questionable if it ever would remove it.

LEGAL QUESTIONS, ETC.

How land is to be obtained for the construction of reservoirs and debris barriers, and what legislative action is necessary to this end, in the present status of affairs, comes hardly within the province of an engineer to determine. It appears, however, on its face that, to build such extensive works as may be necessary in impounding debris from the mines, the companies formed for the purpose of constructing and carrying on such works, should at all events have the right of eminent domain.

STORAGE OF DETRITUS—ESTIMATES OF THE COSTS OF CONSTRUCTING BARRIERS, AND COST OF STORING THE DEBRIS AND DETRITUS.

The quantity of material which will be stored by any of these barriers will depend on the topography of the country back of it as well as the height of the structure. The angle of rest which material will assume behind any barrier cannot be definitely stated, but, judging from what is seen in the cañons, the detritus will take fully as heavy grades behind any obstruction as has been seen along the line of the streams. In the official estimates made of the storage of material behind a proposed debris barrier to be placed at the Narrows it was assumed that the grade of the stream would be from 14 to 15 feet per mile. The annexed table shows in detail the estimated storage capacity and cost of such a work.*

*See Ex. Doc. No. 98, House of Representatives, 47th Congress, 1st Session, p. 88.

Table I, Showing Estimate for the Narrows Dam.

Grades of Storage Prisms, 14 Feet per Mile.

No. of Dam.	Height.	Total height.	Contents of dam.	Storage capacity.			Ratio of stone in dam to stored material.	Cost of dam and reservoir.					Cost per yard of stored material.	Number of years the storage will last.
				In the Yuba, below the South Fork.	Probable additional storage in forks.	Total.		Cost of stone in dam, per cubic yard.	Cost of dam.	Contingencies 10 per cent.	Damages.	Total cost		
	Ft.	*Ft.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*							*Cts.*	
1	75	75	204,345	25,518,565	.....	25,518,565	124	$1 00	$204,345	$20,434	$50,000	$224,779	0.85	1.4 +
2	25	100	59,496	17,753,438	7,000,000	24,753,438	416	1 25	74,370	7,437	.....	113,807	0.45	1.3
3	25	125	65,989	20,695,382	10,500,000	31,195,382	457	1 25	82,486	8,248	.....	90,734	0.29	1.8 +
4	25	150	73,471	23,637,326	13,500,000	37,137,326	491	1 50	110,206	11,020	.....	121,226	0.33	2.1
5	25	175	81,958	26,579,270	15,000,000	41,579,270	507	1 50	122,937	12,293	.....	135,230	0.33	2.4 +
6	25	200	89,918	29,521,214	17,000,000	46,521,214	518	1 50	134,877	13,487	.....	148,364	0.32	2.7 +
.....	25	225	98,000	32,463,158	20,000,000	52,463,158	533	1 50	147,000	14,700	.....	161,700	0 31	3.0 +
Total	....	....	673,177	176,168,353	83,000,000	259,168,353	382	.....	.....	.....	.....	995,840	0.39	15.0

The following estimate in tabular form, is the one given in Ex. Doc. No. 98, House of Representatives, 47th Congress, 1st Session, pp. 89 and 90, for a debris barrier which might be constructed at Point De Guerre.

"The first obstruction and estimated delay on a grillage 3 feet thick, and to be 10 feet high with slopes of 1 to 1 and 1 to 3. The crest width is 10 feet; the second and third barriers are to be of similar shape, and are respectively 6 and 5 feet in height, resting on grillage 3 feet thick.

The erection of this barrier would avoid the necessity of one at the Narrows for some years.

Stone is abundant on the south bank, and a limited quantity at hand on the north bank. The material is similar to that at the Narrows.

The estimates for retaining-capacity are based on a grade of 10 feet per mile; the lightest grade existing in the reservoir space above is 10.5 feet per mile. No estimate is made for the extension of material over the flat lands known to exist above in limited area.

The estimate is based upon work done in July, 1880, under the State Engineer.

This series of dams is estimated to cost per linear foot as follows:

1. *Dam* 10 *feet high,* 10-*foot crest.*

Excavation, 8.888 cubic yards, at 12½ cents	$1 11
Covering mattress, 1.11 cubic yards, at 12½ cents	14
5.11 square yards mattress, at $1	5 11
Grillage, 3.5 logs 20 feet long, 15 to 8 inches in diameter, 2 logs 30 feet long, 15 to 8 inches diameter	5 50
Laying, fastening, etc.	2 50
12.223 cubic yards rock, at $1.35, 10 per cent. added for settlement	16 50
Cost per foot	$30.86

2. *Dam* 6 *feet high,* 10-*foot crest.*

3 trees 8 to 15 inches diameter, 20 feet long, at $1	$3 00
Placing, fastening, etc.	1 00
5.3778 cubic yards stone, at $1.50	8.067
Cost per linear foot	$12.067

3. *Dam 5 feet high, 8-foot crest.*

3 logs 15 to 8 inches diameter, at $1	$3 00
Laying, fastening, etc	1 00
3.66 cubic yards stone, at $1.50	5 49
Cost per foot	$9 49

Table showing estimate of cost and effect of dams at De Guerre Point.

Number.	Height.	Length.	Cost.	Cost, contingencies, damages, etc.	Total cost.	Storage capacity.	Cost per cubic yd. stored.
	Feet.	*Feet.*	*Per foot.*			*Cubic yards.*	
1	10	5,552	$30 86	$71,325 72 17,132 57 20,000 00	$208,458 29	24,800,000	$0.0084
2	6	5,552	12 067	66,995 98 6,699 59	73,695 57	19,500,000	.00326
3	5	5,552	9 49	52,688 48 10,537 69	63,226 17	17,500,000	.00361
Total	21			$345,380 03	$345,380 03	61,800,000	

Succeeding dams will cost about the same as the third, and will increase in storage capacity; the area available above is about 4.25 square miles, or 2,720 acres. To the cost of the first dam is added $20,000 to cover the condemnation of several pieces of property in the area above the dam; to the cost of the third are added contingencies of 20 per cent., as it will then, if not before, be necessary to erect a short piece of dike on the south bank of the river. This dike may be shortened and thrown on better ground by shifting the south end of the dam some 1,400 feet up stream. The change will not materially affect the length nor the amount of material in the dam, but will leave the northern end on lower ground, and necessitate that end of the structure being higher; unequal settlement may then be expected, and a concentration of water at the point of greatest settlement. The line of dike which would be necessary is very short — not over 3,000 feet at the farthest — and need not exceed 5 feet in height for the second dam, with successive additions as the dams are carried higher.

The dike line is much improved by shifting the south end of the dam 1,400 feet above the point shown in the map of the

locality as being the south end of the dam line. The small stream entering just above the dam may be passed around the dike, into the river below the dam, or be included in the reservoir space by running the dike on its south bank to equally high ground; the latter is respectfully suggested."

CONCLUSION.

In reviewing the situation of affairs as shown in this paper, it will be noted that there is no novel engineering feature presented in the question of impounding debris. In Vol. I. of the transactions of this Society, Mr. Geo. J. Specht has called attention to the methods employed in Southern and Central Europe for "treating and controlling sediment-carrying torrential streams." This subject has been treated in detail in many works, especially by Professor Dr. Arthur Freiherrn von Seckendorff, of Austria, and Paul Demontzey, Inspecteur General, Chef du Service de reboisement, France. Reference has been made to the works in India and in other parts of the world, and more data are available. Masonry structures have been excluded on account of the expense which they entailed. It is evident that no unusual difficulties are presented in the construction of debris barriers in this country.

There appears to be, among a class of people other than engineers, a dread of catastrophe from the failure of the works proposed. That at the present date there exists such opinions, is a matter unworthy of discussion.

The barriers here might have a greater height than those which have been described in India; but this, where material is in abundance, is merely a matter of financial detail.

Leaving the mining interests out of consideration, remedial measures will, in the future, be necessary for the protection of the valleys of California, and the conservation of the navigable streams. It is unfortunate that the conflict between the miners and farmers has entered the domain of politics. That the mining and agricultural interests should work in harmony, and that the decline of the former industry is ultimately followed by that of the latter, are facts shown by historical precedents; and there is no reason why, in the present state of affairs, an amicable and equitable settlement should not be reached.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME IV.—JANUARY 7, 1887.)

MINUTES OF MEETINGS.

REGULAR MEETING.

December 3, 1886.

Owing to the absence of the gentlemen who had signified their intention of discussing Mr. John Richard's paper on "The High Pressure Hydraulic System of Distributing Power in Cities," the discussion was postponed.

The following were appointed as a nominating committee to select the "regular ticket" for the annual election. Ross E. Browne, H. C. Behr, F. Gutzkow, H. F. Eckert and Milo Hoadley.

REGULAR MEETING.

January 7, 1887.

Vice-President Specht in the chair.

Minutes of preceding meeting read and approved.

The election of Otto Von Geldern and Ferd. Hellman was reported by the committee which counted the ballots.

Wm. Francis Herrick was proposed for membership by C. G. Yale, W. H. Smyth, G. F. Allardt.

The nominating committee reported the following nominations for the regular ticket for 1887:

For President—Geo. H. Mendell.
For Vice-President—Geo. J. Specht.
For Secretary—Chas. G. Yale.
For Treasurer—Marsden Manson.
For Directors—Geo. W. Dickie, Aug. J. Bowie, Jr., G. F. Allardt, E. J. Molera, F. Von Leicht.

G. F. Allardt explained the plan of Board of Public Works proposed by the Freeholders, and read certain changes and additions to certain clauses which it was proposed to suggest to the Freeholders. Mr. Allardt said the proposed amendments must be handed in to the Freeholders immediately, and there was no time to appoint a committee to consider them.

Mr. Browne asked whether the Technical Society of the Pacific Coast or any member had been asked for suggestions.

The Chairman said that no such request had been made by the Freeholders, but in the interests of the engineering profession, this movement had been suggested by some of the members.

Mr. Browne asked in what form it was proposed to place these suggestions before the Board as coming from the Technical Society.

Mr. Allardt thought we should consider and adopt the suggestions brought forward, and then appoint a committee to transmit our suggestions to the committee of Board of Public Works of the Board of Freeholders.

Mr. Allardt moved to take up *seriatim* the proposed amendments.

Mr. Molera moved that the President appoint a committee of three to confer with the Freeholders after adopting the amendments suggested.

Mr. Bowie objected to hasty action, and thought it was questionable for the Society to move before looking further into the subject.

Mr. Allardt said that the Freeholders expected a communication from the Society.

Mr. Molera said we had received assurances that our suggestions would be received and considered by the committee.

Mr. Bowie objected to our going into political matters and committing the Society.

Mr. Allardt said we merely desire to advise concerning the salary and duty of the City Engineer.

Mr. Hoadley asked if the charter was to be subjected to popular vote, and was answered yes. He did not see why the office of City Surveyor was abolished.

Mr. Bowie agreed with Mr. Hoadley with regard to deficiency of city surveys. He thought a very good man should be given the position of City Engineer. He indorsed the ideas read by Mr. Allardt. It would be most desirable for us to be able to suggest improvements to the Freeholders, but he questioned the propriety of going before these gentlemen in too hasty a manner and the policy of the Society committing itself too hastily.

Mr. Molera withdrew his motion concerning the committee.

Mr. Allardt moved that this Society appoint a committee to wait on the Board of Freeholders with the suggestions to be adopted at this meeting. This motion was carried by a vote of 13 ayes to 3 noes.

Mr. Molera moved that the committee send to the Board of Freeholders the amendments read at this meeting, and no others. The motion was not seconded.

Mr. Allardt thought that the proper course to pursue would be to consider the amendments *seriatim*.

Mr. Browne thought it important that the amendments suggested should be put in form of mere suggestions, and modestly so, in order that the Board of Freeholders will not think we are meddling with their business.

Mr. Dickie thought that the suggestions, if made, should be made with all the force of the Society. At the same time he thought action was too hasty. He asked if the Board was elective or appointive.

Mr. Allardt said the Board was to be appointed by the Mayor for four years.

Mr. Dickie thought if there was a possibility of making the engineer a sort of political officer we ought not to trouble ourselves with the question of his salary.

Mr. Allardt said we simply make suggestions to the Freeholders, but do not dictate.

Mr. Dickie suggested that the salary in question in the proposed amendments should be left out. As to the duties, all right; but as to salary we should say nothing, as the amount is ridiculous, and the salary question should not enter into our suggestions. Our suggestions would be stronger without it.

Mr. Browne thought Mr. Dickie's point a good one, and we should say, "a suitable salary," instead of "$6,000 per annum.'

Mr. Browne moved that the question of amount of salary be omitted from the proposed amendments, and that a committee be appointed to present these amendments as suggestions of the Technical Society of the Pacific Coast.

Withdrawn.

Mr. Allardt moved to consider the amendments *seriatim.*

Mr. Browne moved the adoption of the amendments suggested with the exception of the question of salary.

Mr Vischer wanted to know if this committee must go charged with special instructions.

Mr. Gutzkow was unwilling for the Society to accept the responsibility of resolutions or amendments too hastily.

Mr. Allardt moved that the Society now suggest amendments to these amendments, but the motion was not seconded.

Mr. Von Leicht moved that the amendments read by Mr. Allardt, including the question of salary, be adopted. There were 7 ayes and 7 noes, and the Chairman decided in favor of the motion.

Mr. Bowie suggested that the President of the Society be added to whatever committee was appointed.

Vice-President Specht appointed Messrs. Allardt, Mendell and Von Leicht.

Mr. Molera moved postponement of the discussion of Mr. Richards' paper until next meeting.

Mr. Richards said he might prepare a short supplement to his paper for next meeting, if desired.

ANNUAL MEETING.

January 28, 1887.

The meeting was not called to order. H. C. Behr and Ernest L. Ransome, acting as tellers, counted the ballots which had been sent by mail, and announced the result of the annual election as follows:

President—Geo. H. Mendell.
Vice-President—Geo. J. Specht.
Secretary—Chas. G. Yale.
Treasurer—Marsden Manson.
Directors—Geo. W. Dickie, Aug. J. Bowie, Jr., G. F. Allardt, E. J. Molera, F. Von Leicht.

REGULAR MEETING.

February 4, 1887.

President Mendell in the chair.

On motion, the reading of the minutes was dispensed with.

Messrs. Manson and d'Erlach, acting as tellers to count ballots, reported the election of the following gentlemen:

S. Harrison Smith, proposed by Col. G. H. Mendell, L. J. Le Conte and Hubert Vischer.

J. C. H. Stut, proposed by G. W. Wepfer, E. C. Burr and H. C. Behr.

Wm. F. Herrick, proposed by C. G. Yale, W. H. Smyth and G. F. Allardt.

W. C. Ralston, proposed by G. F. Allardt, Wm. Minto and J. B. Hobson.

Nathaniel S. Keith was proposed by C. G. Yale and G. W. Dickie.

Aug. J. Bowie, Jr., read a paper on "Mining Debris in California Rivers."

On motion, it was resolved that the Society receive Mr. Bowie's paper in full and that the discussion on Mr. Richards' paper be postponed.

Mr. L. L. Robinson stated that certain statistics in Mr. Bowie's paper could be utilized by members of the Legislature, and asked if there would be objection to his using these statistics before publication by the Society. It is desirable to obtain this. He asked permission to use this paper.

Mr. Price moved and Mr. Robinson seconded, that the paper be accepted and the thanks of the Society passed to Mr. Bowie.

REGULAR MEETING.

March 4, 1887.

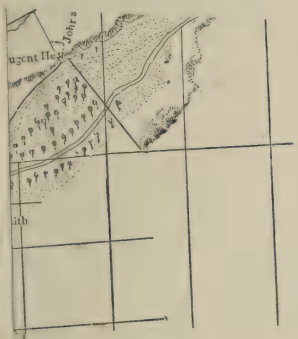
President Mendell in the chair.

Minutes of preceding meeting read and approved.

M. G. Wheeler was proposed for membership by F. Von Leicht, J. R. Mauran and Geo. J. Specht.

Aug. J. Bowie, Jr., read a continuation of his paper on "Mining Debris in California Rivers."

Approved.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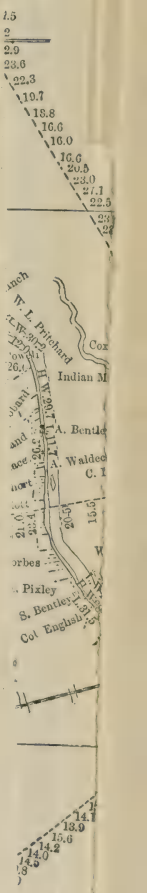
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JOHNSON RANCHO
WHEATLAND
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Coon Creek
NICOLAUS
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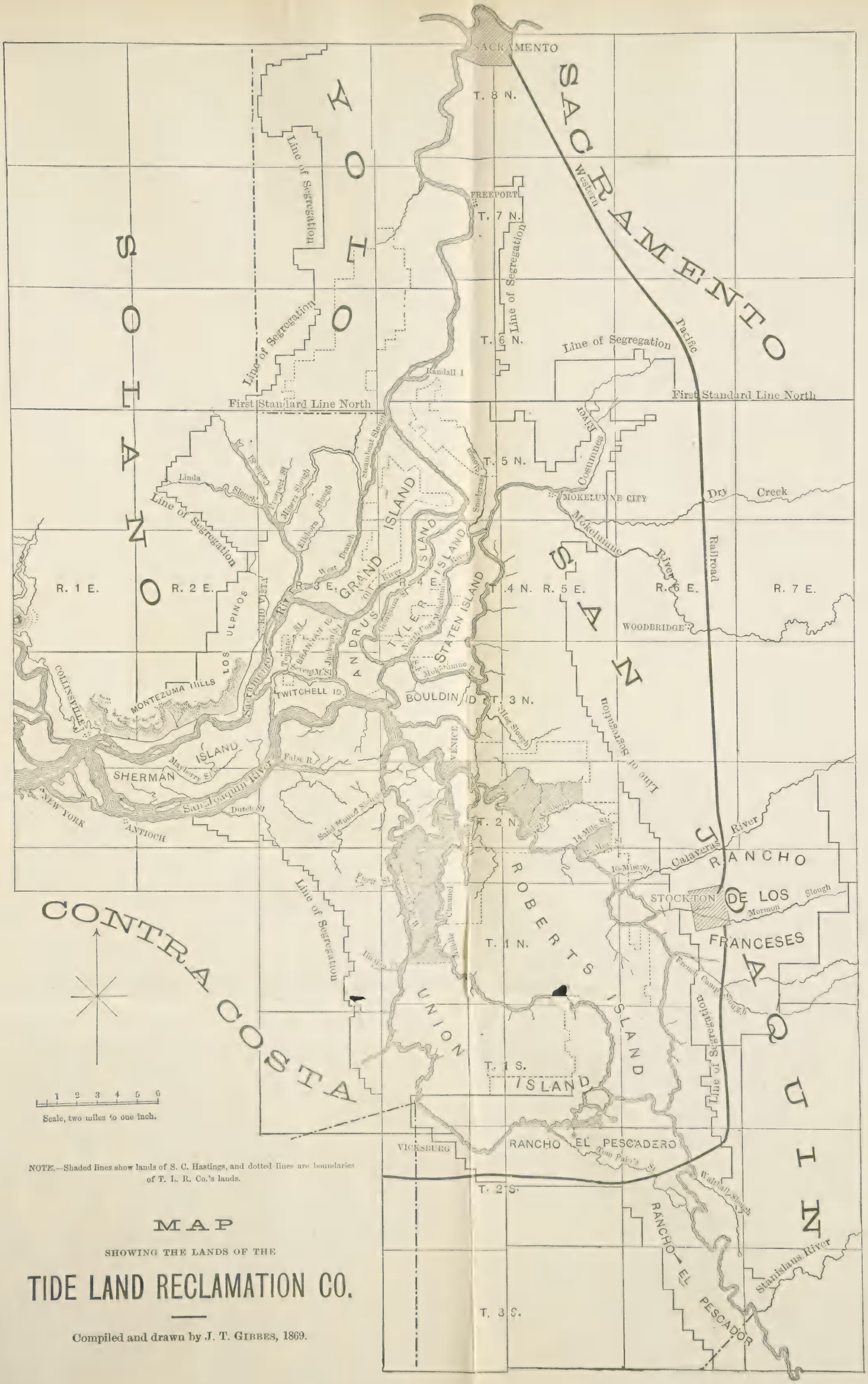
T. 12 N. R. 4 E.
T. 11 N. R. 3 E.
T. 11 N. R. 4 E.
RANCHO RIO JESUS MARIA
GRAY'S BEND
HAYES' LANDING
T. 10 N. R. 3 E.
T. 10 N. R. 4 E.
RANCHO DEL PASO
T. 9 N. R. 3 E.
T. 9 N. R. 4 E.
SACRAMENTO
RANCHO
American River
BRIGHTON
T. 8 N. R. 3 E.
T. 8 N. R. 5 E.
LEGEND
Streams
Old alignment of water courses
Roads
Railroads
H. W. High water
L. W. Low water.
L. Levee.
Lines of exact survey.
Contour lines.
Fences
Ranch boundaries:
Land covered by sand and sediment.
Elevations are above low water Suisun Bay
Ground covered with brush
Swampy ground.
Scale—one inch to 3000 feet.



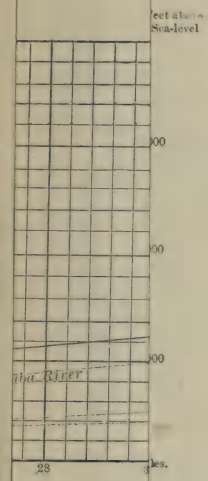
NOTE.—Shaded lines show lands of S. C. Hastings, and dotted lines are boundaries of T. L. R. Co.'s lands.

MAP

SHOWING THE LANDS OF THE

TIDE LAND RECLAMATION CO.

Compiled and drawn by J. T. GIBBES, 1869.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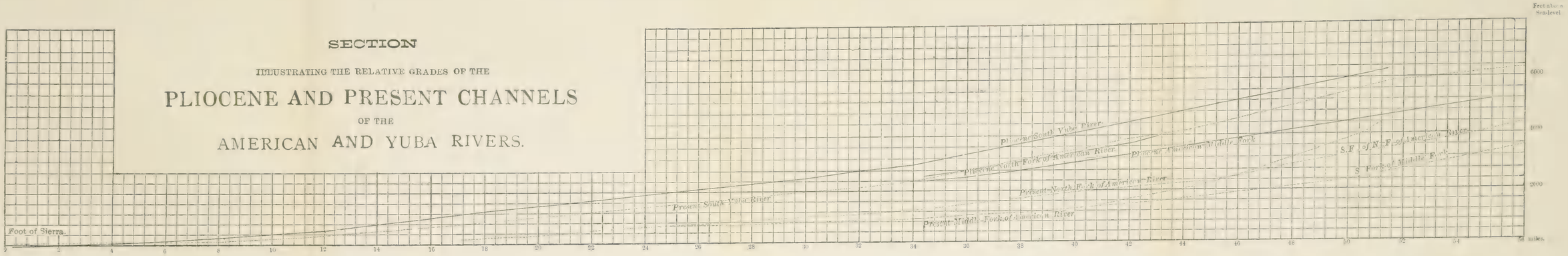
SECTION

ILLUSTRATING THE RELATIVE GRADES OF THE

PLIOCENE AND PRESENT CHANNELS

OF THE

AMERICAN AND YUBA RIVERS.



UNION CI
Union City

MAP

EXHIBITING THE

Salt Marsh, Tide and Submerged Lands

DISPOSED OF BY THE

STATE OF CALIFORNIA,

IN AND ADJACENT TO THE

BAYS OF SAN FRANCISCO

AND

SAN PABLO.

SAN PABLO BAY
Napa Creek
VALLEJO
Pt Wilson
Point Pt
Point San Pablo
Pt Richmond
Castro Rocks
Mobile Pt
Pt San Pablo
Pt Pinole
Pt Cam Quellin
California Peg Pt
Point Pt
Pt Pinnacle Pt
Pt Bonita
Pt Cavallo
Lupe Pt
Pt Diablo
SAN FRANCISCO BAY
THE LANDS GRANTED TO THE CITY OF OAKLAND
YERBA BUENA I
OAKLAND
BROOKLYN
ALAMEDA
SAN LEANDRO
Alameda C. R.
Pt San Quentin
Pt Atlanticus
Pt San Bruno
Pt Pt
Pt San Bruno
Shell Banks
Pt Point Molate
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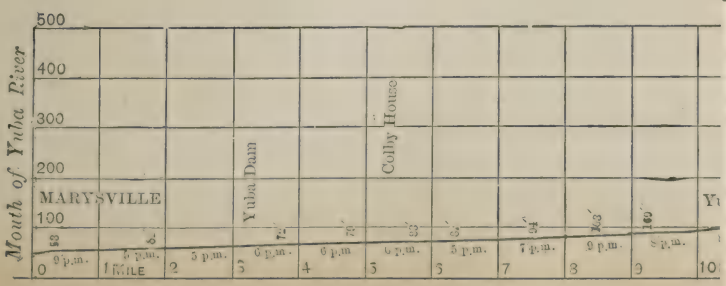
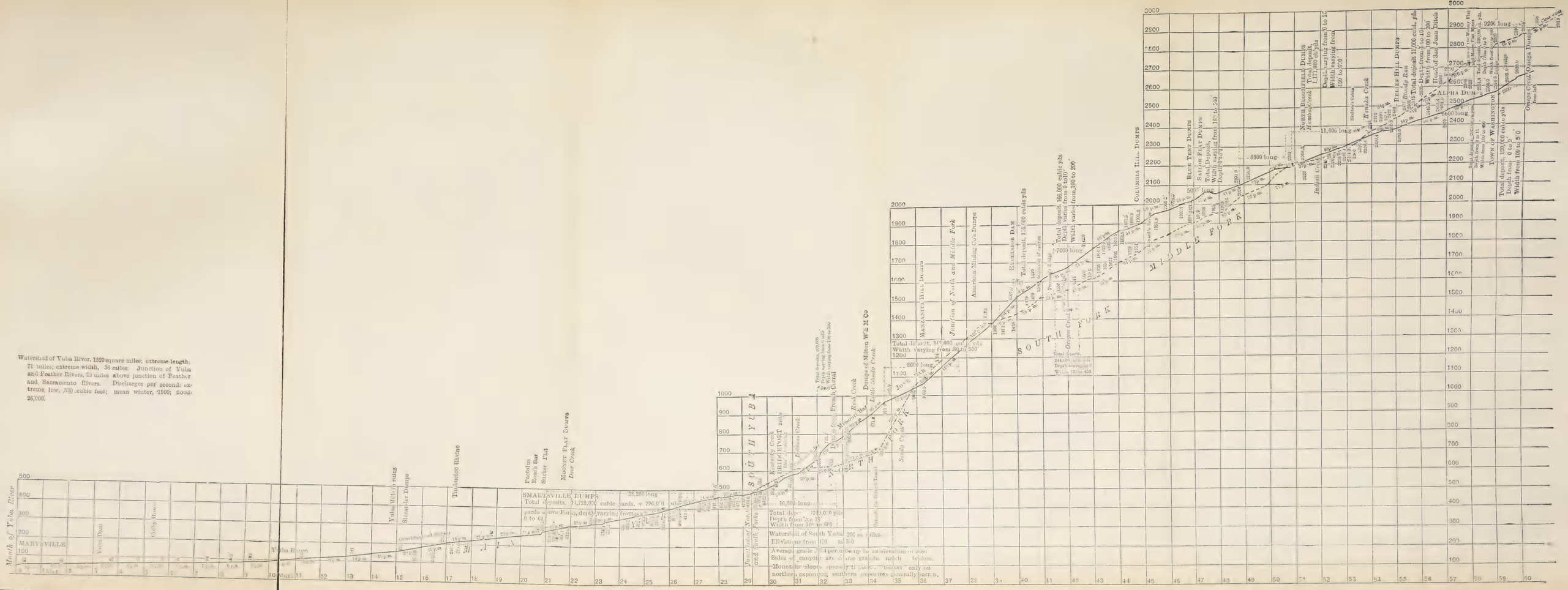
Watershed of Yuba River, 1329 square miles; extreme length, 71 miles; extreme width, 36 miles. Junction of Yuba and Feather Rivers, 29 miles above junction of Feather and Sacramento Rivers. Discharges per second: extreme low, 500 cubic feet; mean winter, 1500; flood, 26,000.



Watershed of Yuba River, 1329 square miles; extreme length, 71 miles; extreme width, 36 miles. Junction of Yuba and Feather Rivers, 29 miles above junction of Feather and Sacramento Rivers. Discharge per second: extreme low, 539 cubic feet; mean winter, 2500; flood, 26,000.



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME IV.—APRIL, 1887.)

A NEW METHOD OF DIFFERENTIATION.

BY H. T. COMPTON, M. Tech. Soc.

Read April, 1887.

The object of this paper is to explain a new method of obtaining the differentials of functions of a single variable or of several variables, which is believed by the writer to be logical and conclusive, and to leave no doubts in the mind of the student as to its absolute correctness. In no text-book on calculus which the writer has seen, is there a clear proof that the limit of the increment of the function divided by the increment of the variable, is equal to the ratio of the differential of the function to the differential of the variable. All that is proved in the operations in the text-books in question, is a particular value for the symbol $\frac{0}{0}$ for each particular case.

By what right of reasoning do the authors of these text-books substitute $\frac{dy}{dx}$ for $\frac{0}{0}$?

That the conclusion is jumped at seems evident.

The writer suggests the following method of differentiation, which at least is original, so far as he knows :

$$\text{Let } y = f(x)$$

let dx be the assumed rate or velocity of the variable expressed in units of the same kind as x, per unit of time, and let dy be the corresponding rate of the function, per unit of time.

Let time be represented by t.

Now suppose x to increase uniformly for t units of time, it will receive an increment $= dx\,t$. y will receive in the same time, assuming its velocity to continue uniform, the increment $dy\,t$. Substituting in the 1st equation for y and x their new values $(y + dy\,t)$ and $(x + dx\,t)$, we have

$$y + dy\,t = f(x + dx\,t.)$$

$$\text{Sub.} \qquad y = f(x)$$

$$dy\,t = f(x + dx\,t) - f(x)$$

$$dy = \frac{f(x + dx\,t) - f(x)}{t.}$$

Generally this is only true when $t = 0$. The only exception being in the case of functions which increase uniformly when the variable increases uniformly.

It is always true when $t = 0$.

Making $t = 0$ we have

$$dy = \left(\frac{f(x + dx\,t) - f(x)}{t}\right)_{t = 0}$$

Here we have found the value of the dy directly in terms of x and the dx, by a simple and clear algebraic process.

By making $t = 0$ we correct any possible error arising from the assumption that y increases uniformly with x.

Let us now illustrate by a few particular cases.

FIRST.

$$\text{Let } y = x^n$$

$$y + dy\,t = (x + d\,t)^n$$

$$y + dy\,t = x^n + nx^{n-1}dx\,t + \frac{n\,(n-1)}{2}\,x^{n-2}\,dx^2\,t^2 \text{ --- } dx^n\,t^n$$

$$dy\,t = nx^{n-1}\,dx\,t + n\,\frac{(n-1)}{2}\,xn^{n-2}\,dx^2\,t^2 \text{ --- } dx^n\,t^n$$

$$dy = nx^{n-1}dx + \text{terms containing } t$$

$$\text{making } t = 0$$

$$dy = nx^{n-1}\,dx.$$

$$\frac{dy}{dx} = nx^{n-1}$$

SECOND.

Functions of two independent variables:

$$\text{Let } u = x + y$$

$$u + Du\,t = x + dx\,t + y + dy\,t$$

$$Du\,t = dx\,t + dy\,t$$

This is true for all values of t, because in this case the velocity of increase of the function is uniform—

$$\therefore\ Du = dx + dy.$$

THIRD.

$$u = x^2 + y^3$$

$$u + Du\,t = (x + dx\,t)^2 + (y + dy\,t)^3$$

$$u + Du\,t = x^2 + 2\,x\,dx\,t + dx^2\,t^2 + y^3 + 3y^2\,dy\,t + 3ydy^2\,t^2 + dy^3\,t^3$$

$$Du\,t = 2\,xdx\,t + dx^2\,t^2 + 3y^2\,dy\,t + 3\,y\,dy^2\,t^2 + dy^3\,t^3$$

$$Du = 2\,x\,dx + dx^2\,t + 3y^2\,dy + 3ydy^2\,t + dy^3\,t^2$$

making $t = 0$

$$Du = 2\,x\,dx + 3y^2\,dy$$

$$\text{or } Du = du_x + du_y$$

FOURTH.

Let $u = x^2 + 2\,xy + y^2$

$$u + Du\,t = (\,x + dx\,t\,)^2 + 2\,(x + dx\,t)\,(y + dy\,t) + (y + dy\,t)^2$$

$$u + Du\,t = x^2 + 2\,xdxt + dx^2\,t^2 + 2\,xy + 2\,x\,dy\,t + 2ydx\,t + 2\,dx.\,dy.\,t^2 + y^2 + 2y\,dy\,t + dy^2\,t^2$$

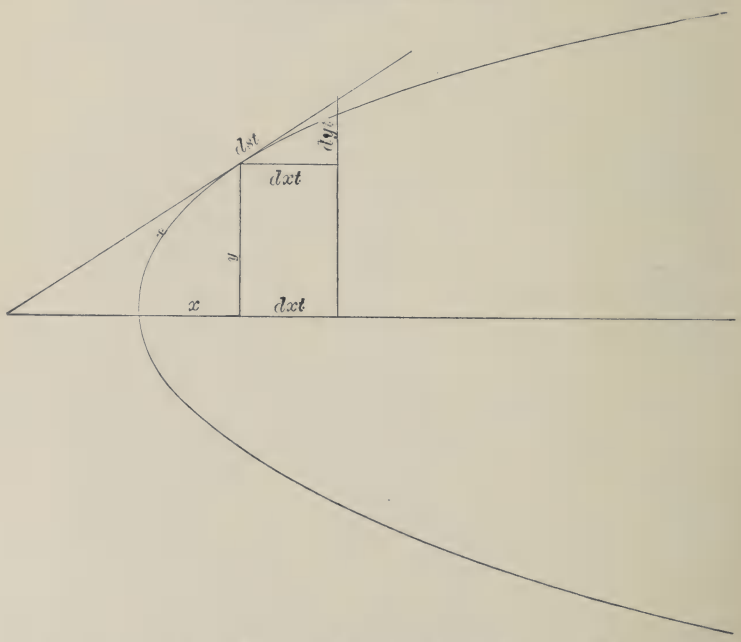
$$Du\,t = 2\,x\,dx\,t + dx^2\,t^2 + 2\,x\,dy\,t + 2\,y\,dx\,t + 2\,dx\,dy\,t^2 + 2\,y\,dyt + dy^2\,t^2$$

dividing both members by t. and then making $t = 0$.

$Du = 2\,xdx + 2\,xdy + 2\,y\,dx + 2\,y\,dy$ in which it is seen that the total $Du =$ the sum of the partial diffs. with respect to x and y.

FIFTH.

DIFFERENTIAL OF AN ARC.



Take any arc s and draw a tangent at the point whose co-or-

dinates $= x$ and y. The increment of the arc $= ds\,t$ will lie in the direction of the tangent, in order to conform to the hypothesis that the ds continues uniform for the time t.

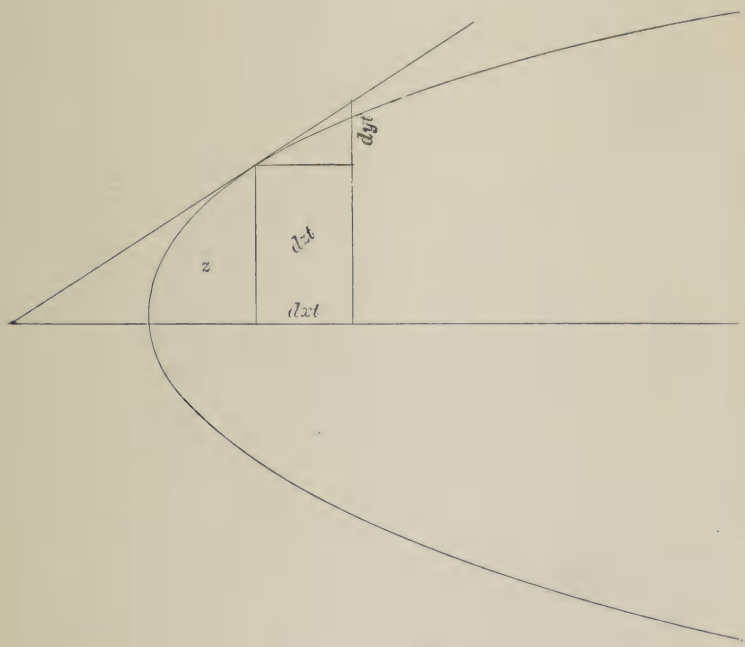
It is then easily seen from the figure, that

$$(ds\,t)^2 = (dx\,t)^2 + (dy\,t)^2$$
$$ds^2 = dx^2 + dy^2$$

Also that $\frac{dy\,t}{dx\,t} = \frac{dy}{dx} =$ nat. tang. of the angle that a tangent to the curve makes with the axis of abscissas.

SIXTH.

DIFFERENTIAL OF AN AREA.



$$dz\,t = dx\,t\left(y + \frac{dy\,t}{2}\right)$$

$$dz\,t = dx\,yt + \frac{dx\,dy\,t^2}{2}$$

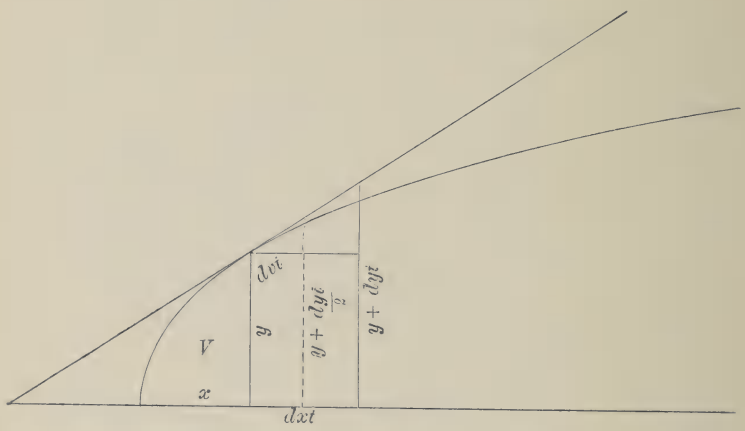
$$dz = dx\, y + \frac{dx\, dy\ t}{2}$$

making $t = 0$

$$dz = dx\, y$$

SEVENTH.

DIFFERENTIAL OF A VOLUME OF REVOLUTION.



$d\ v\ t$ will be a frustum of a cone, the radius of the upper base being y of the lower base $y + dy\ t$, and of the mean proportional between the two bases $y + \frac{dy\ t}{2}$ and the height being $dx\ t$.

$$dv\ t = \tfrac{1}{3}\ dx\ t\ .\ \pi\ y^2 +$$
$$\tfrac{1}{3}\ dx\ t\ .\ \pi\ (y^2 + y\ dy\ t + \frac{dy^2\ t^2}{4}) +$$
$$\tfrac{1}{3}\ dx\ t\ .\ \pi\ (y^2 + 2\ y\ dy\ t + dy^2\ t^2)$$

adding and dividing through by t

$$dv = \quad y^2\ dx\ \pi + y\ dy\ t\ 2\ dx + \frac{5}{12}\ dy^2\ t^2\ 2\ dx$$

making $t = 0$

$$dv = \quad y^2\ dx\ \pi$$

In a similar manner may be found the diff. of a surface of revolution.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

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THE TRANSMISSION OF POWER BY MEANS OF ELECTRICITY.

BY N. S. KEITH, ELECTRICAL ENGINEER, MEM. TECH. SOC.

Read April 1, 1887.

What is electricity? Why is it a means of transmitting power? And why has its usefulness in that line been so long overlooked and unutilized? These are questions which are asked every day, together with a thousand others, implying either ignorance or incredulity, or both.

In the matter of the production and utilization of electricity great strides have been made within the last decade — yes, even within the past two years; so that many things which were viewed as problematical, even in the scientific world, a very few years ago, have become assured commercial facts, owing to the improvements made by experimenters and manufacturers in apparatus for generating electricity, and in other apparatus for making it useful to mankind.

What is electricity? It is a mode of motion. It is a manifestation of the existence of active energy; and this manifestation is made only in assemblages of materials, which assemblages we call electrical. We have no sense by which to recognize electricity as we have to recognize heat, light, sound, taste and smell. We only recognize it secondarily by the aid of instruments which exhibit their indications to our senses. There is no such thing, considered as an entity, as electricity, any more than there is a material heat or light. It is, then, only a

motion of matter and called electricity. Being matter in motion it is produced by motion of assemblages of matter, and communicates motion to still other assemblages of matter. It is probable that if we could electrically insulate all forms of matter in motion we would find by electrical indicators electrical reactions. Heat, light, sound, chemical affinity, mechanical motion, etc., produce electricity; and electricity produces them, all in return. That which is necessary in each case is to provide the proper assemblages of material which experience has taught us, or investigation may teach us, to be one from which we can or may produce the required action. Being then itself a mode of motion, produced and sustained by motion, what more suitable for communicating motion?

Why is its usefulness in the direction of transmitting power only now being recognized commercially? Let me answer this question by devoting a little time in considering its history, because I think, besides being interesting, the answer to the question will then be obvious to all.

In 1819, Oersted first observed that when a current of electricity is caused to flow in a wire placed parallel to, and in the neighborhood of, a magnetic bar, like a compass needle, the bar is deflected from its position, if free to move, and tends to place itself in a direction perpendicular to the electric wire, and that the extent of the deflection of the needle is determined mainly by the strength of current of electricity in the wire. By a "current" of electricity we mean the motion taking place in the molecules of the electric wire. The term "current" is a relic of the time when electricity was theoretically considered to be an imponderable fluid which moved from place to place.

Oersted's wire and needle was an electric motor, incipient to be sure, but the germ from which great things have grown. From the experiment we learn that electricity can move matter. For several years, beginning about the year 1830, Faraday experimented in the line of investigation opened by Oersted's discovery, and published in his *Experimental Researches* his experiments, deductions, theories, etc. In his publications he gave to the world the principles governing electro-magnetism, and clearly foretold the electromotor which he, in his ardor for

original research, omitted to make of practical utility. But others, building on his foundation, made electric motors which they put to use.

"The first electro-magnetic engine which was something more than a mere model, was constructed by Prof. Jacobi of St. Petersburg, in 1834. In 1838 he succeeded in propelling a boat, containing ten or twelve persons, on the River Neva. The vessel was a ten-oared shallop, equipped with paddle wheels, to which rotary motion was communicated by an electro-magnetic engine. The boat was 28 feet long and 7½ feet in width, and drew 2¾ feet of water. During a voyage which lasted several days the vessel went at the rate of four miles per hour. In 1839 Jacobi tried a second experiment in the same boat. The machine, which was the same as that used on the previous occasion, and which occupied little space, was worked by a battery of 64 platinum plates, each having 36 square inches of surface, and charged, according to the plan of Grove, with nitric and sulphuric acids. The boat, with a party of fourteen persons on board, went *against* the stream at the rate of three miles per hour."

"In 1842, Davidson's electro-magnetic engine was built, and tried by the inventor on the Edinburgh and Glasgow Railway. It weighed with its carriage, batteries, etc., five tons, but when put in motion on the rails, it only traveled four miles an hour, thus exhibiting a power less than that of a single man."

"In 1850, Page exhibited one of his engines, of between four and five-horse power, at the Smithsonian Institution, the battery to operate which was contained within the space of three cubic feet. It was a reciprocating engine of two-feet stroke, and the whole, including the battery, weighed about one ton. Page stated that the consumption of three pounds of zinc per day would produce one-horse power. But Joule's estimate is widely different; he calculates that in an electro-magnetic engine constructed most favorably to prevent loss of power, the consumption of zinc per twenty-four hours to produce one-horse power is in Grove's battery forty-five pounds, and in Daniell's battery seventy-five pounds."

The dynamic value of a pound of zinc combining with an

equivalent amount of sulphuric acid, is 2,100,000 foot pounds. Therefore if the electro-magnetic engine had been a theoretically perfect one, one pound of zinc in a perfect battery would have yielded a little over one-horse power for each hour, or twenty-four pounds would be required in twenty-four hours. But the motor, as we now know, was far from being perfect, and a galvanic battery does not utilize the full dynamic value of the zinc and acid. It is therefore evident that Page's statement was much too small. A host of experimenters and inventors of motors arose, but their inventions never came to commercial success, owing to at least two reasons: The inefficiency of their motors in converting electrical into mechanical energy; and the great cost of that electrical energy when produced by the union of zinc and acid in even the best possible constructions of batteries.

Now let us turn to the rise of the mechanical generator of electricity. It was reserved for Faraday to show in 1830, preliminarily, how electricity could be produced by mechanical motion. Arago had previously (1824) shown that when magnets were moved in certain directions relatively to disks or other forms of metals, motion was imparted to the disks without the magnets even touching them. He also showed that conversely the disks when moved would impart motion to the magnets. The discoveries of Faraday explained these phenomena, and showed plainly that they were due to electricity — that when conductors were moved in the neighborhood of magnets, currents of electricity were induced in the conductors, and that the conditions so set up were such as to oppose the motion. Therefore if the magnet was free to move it moved with the conductor.

Conversely: If the magnet was moved in the neighborhood of the conductor the conductor had set up in it an electric current which opposed the motion; and if the conductor was free to move, it followed the magnet.

These facts having been discovered and given to the world, experimenters and inventors soon made machines for moving the wires and magnets for the purpose of producing electricity. Faraday had also shown that when currents of electricity were

caused to flow through wires coiled around iron cores the iron cores became strongly magnetic; and, conversely, when magnetic masses were moved within coils of wire, connected in circuit, currents of electricity were produced in the coils. Therefore the inventor had a short road to travel in the effort to gain a machine for the generation of electricity.

In 1832, Pixii exhibited his electric generator to the Academy of Sciences in Paris. This generator consisted of a steel permanent magnet, before the poles of which two bobbins of wire surrounding the arms of a U-shaped mass of iron were rotated. During rotation of the bobbins fastened on the U-armature before the poles of the magnet the arms of the U-armature were magnetized alternately N. & S. This action induced currents of electricity to flow in the coils. Pixii's machine has been modified in many ways, but mainly in the matter of multiplications of bobbins and magnets. But they have been found highly inefficient and therefore have been abandoned as machines for the production of currents of electricity for most of purposes. The Siemens' modification is in extensive use in the magneto-call attachment to telephonic apparatus. They are useless, no matter what their size, for the purposes of power transmission.

In 1867, Messrs. Siemens and Wheatstone each read during the same meeting of the Royal Society in London papers upon the "Conversion of Dynamical into Electrical Force without the Aid of Permanent Magnetism," in which they both claimed priority in the discovery of what has since been called the "principle of mutual accumulation in dynamo-electric machines." Machines embodying this principle are constructed as follows: The stationary electro-magnet, between the poles of which the electro-magnetic armature is rotated, having once been magnetized, and though of soft iron, retains thereafter a slight magnetism which is denominated "residual magnetism." This residual magnetism is sufficient to induce in the core of the armature-electro-magnet slight changes in its magnetism as it is rotated. These changes produce currents in the armature coils, which currents being conducted through the coils of the stationary electro-magnet increases its magnetism, and that in turn produces stronger changes in the armature magnetism and increase

of current, which increased current increases the several reactions as before stated, until by the mutual accumulations the maximum of current strength from the machine is produced. It will be seen that such a machine is a mechanism for the conversion of the mechanical motion called power into electricity; or, rather, electrical energy. Having the electrical motor by which the electrical energy may be reconverted to power, a conductor joining it with an electrical generator completes a simple system for the transmission of power from one place to another. Up to this time (1869) the electrical generators and motors which had been produced were very defective in the point of efficiency. That is to say, but a very small part of the energy involved was conserved as electricity which could be utilized in the circuits. Most of the energy was practically lost in the way of producing heat, localized currents of electricity which were unutilizable, friction of journals and of the parts against the air, etc.

In 1869 Gramme invented his celebrated electric generator, which is the type of all of the dynamos now made for the production of continuous currents of electricity. Some years thereafter, however, some one discovered that in 1860 Prof. Pacinnoti of the University of Pisa, had made an electric motor embodying the same principles of construction and operation; and that in 1864, in an Italian journal of science, *Il Nuovo Cimento*, he described his motor and the emperiments which he tried with it in the way of lifting weights, etc. He also stated that which had not seemed to have been suspected theretofore, that the electromotor was reversible — that is to say, when its armature was rotated by power it produced currents of electricity. The statements of Pacinnoti made in 1864 did not attract the attention which they richly deserved. He seems to have been far ahead of his time.

The fact that mechanical generators of electricity could be used in connection with motors, was not discovered, or if discovered was not placed in practical use, until the year 1873, at the Vienna Universal Exposition; and then it only occurred to the distinguished electrician, Fontaine, after he had failed to get one of his Gramme dynamos to act as a motor by electricity from his batteries. After thinking the matter over

a whole night he concluded that perhaps he might run it by electricity from his other Gramme dynamo. This he did with success, much to his astonishment and that of others. After several additions of wire to his conductors joining the two machines he had a circuit of upwards of two kilometres, and the arrangement worked a pump with great success. This seems to have been the first case of transmission of power by electricity, even though electric generators and electric motors had been known for forty years. Since 1873 many applications of electricity for the transmission of power have been made; but it is only within the past very few years that the matter has assumed any considerable proportions. In May, 1877, the writer in a paper read before the American Institute of Mining Engineers, considered the problem of conveying 1,000 h. p. the distance of thirty miles from the falls of Niagara. The impracticability of the scheme was decided only upon the fact that the interest on the cost of plant such as then could be built would exceed the cost of coal to produce 1,000 h. p. continuously at the desired locality. But in 1878 machines had not been built which would make a conversion of mechanical to electrical energy of more than 40 per cent. Under that condition all the power which could be transmitted did not constitute more than 40 per cent. of 40 per cent., or 16 per cent. of the primary power. This condition then existing narrowed the availability of an electrical power plant exceedingly.

At the Centennial Exhibition (1876) Mr. William Wallace of Ansonia, Conn., exhibited dynamos and electric motors in operation. In 1881 the firm of Siemens & Halske built the Lichterfelde electric railway in Berlin, and have succeeded it with many others in Europe. The longest, exceeding six miles, is the Portrush Electric Railway in Ireland. Many electric railways are in operation in the United States; and many thousands of motors, varying from fractions of a man power to many horse power, are also run from central stations at which the electricity is generated, after the manner of electric light stations in the cities and towns. And the writer is now building motors for use on electric railways and for power distributing purposes in the cities of the Pacific Coast.

Having thus hastily glanced at the history of electric power, I next beg your attention to a description of a typical dynamo and motor, coupled with considerations of the principles involved.

First, as to principles: All electrical actions and reactions are expressed in units of electro-motive force, resistance and current. *Electro-motive force* is that quality of a source in virtue of which it tends to do work by the transfer of electricity from one point to another. The work done, whether it be mechanical or chemical or thermal, was proved experimentally by Dr. Joule to be proportional to the *square* of the current multiplied by the *time* during which it acts, and by the resistance of the circuit. By the term *electrical resistance* is to be understood that quality of a conductor in virtue of which it prevents the performance of more than a certain amount of work in a given time by a given electro-motive force. By the term *electrical current* is meant the cause of the peculiar properties possessed by a conductor used to join the opposite poles of a source of electricity, such as the effect upon a magnet in its neighborhood, the magnetization of iron, etc. These terms were adopted by the British Association in 1863.

Dr. Ohm laid down the law which governs the relations of these three qualities, and expressed the law algebraically thus:

$$E = C\ R.$$

$$\frac{E}{C} = R.$$

$$\frac{E}{R} = C.$$

In these formulæ E is for electro-motive force; R for resistance; and C for electrical current. To illustrate by the closest analogy: Electro-motive force may be pressure, as of a column of water; resistance the friction of the water in the conducting pipe; and current the cross-section of water passing through. But the analogy is not altogether true, because the current of water is not determined by the pressure or head, divided by the friction of the water against the walls of the pipe. The analogy is often used for purposes of illustrating the point. But it is

apt to mislead. It is better to study the subject upon its own basis.

The unit of electro-motive force is called a *volt*. The unit of resistance is called an *ohm*. The unit of current is called an *ampere*. Ohm's law may then be graphically stated as follows:

$$\frac{\text{Volts}}{\text{Ohms}} = \text{Amperes.}$$

$$\text{Volts} = \text{Ohms} \times \text{Amperes.}$$

$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms.}$$

In 1863, the British Association adopted an electro-magnetic value for the ohm, which value was determined by a process too long and elaborate to here describe. In 1881, the Congress of Electricians in Paris adopted absolute dynamic values for the volt, ohm and ampere, which are based upon the work done by a gramme falling at the rate of a centimetre per second of time. This system of measurement is known as the *c. g. s.* (centimetre-gramme-second) system, and is unquestioned. It has done for electricity what Joule's unit of heat has done for engineering. It has made a unit which is easily convertible into kilogrammetres or foot-pounds. The *c. g. s.* unit is very small — much too small for ordinary use in the art. Therefore the volt, ohm and ampere have been adopted for such use and are valued as follows:

$$\left.\begin{array}{l} \text{Volt} \quad = 10^{8} \\ \text{Ohm} \quad = 10^{9} \\ \text{Ampere} = 10^{-1} \end{array}\right\} \text{c. g. s. units.}$$

There is a unit of power which is called the "watt," after Watt of steam engine fame. The value of the watt is algebraically expressed thus: $C^2 R = E \times C = \text{Volt} \times \text{Ampere} = P = \text{Watt}$. Theoretically and experimentally the value of a watt has been determined to be the $\frac{1}{746}$ part of a horse-power, 746 watts = 33,000 foot-pounds.

Electricians have instruments which are modified galvanometers, called respectively Voltmeters, Ohmmeters and Ammeters, and authentically calibrated at least as closely as a

foot rule, a pound weight or a clock second of time. Knowing any two of the three quantities—ohm, volt and ampere—the other can be calculated by simple multiplication or division under Ohm's law. And so equally well the dynamic value or foot-pounds. I make these statements so elaborate for two reasons—(1) to elucidate my subject, and (2) because the statement has been made before this Society that "Electricians, for some reason, seem to avoid a conversion of their terms into foot-pounds and horse-power, and it is with some difficulty one learns the dynamic value or money value of the amount of power that can be transmitted and applied by a second motor. This I construe as a significant fact in electrical science, because, if electricians could see 'hope and promise' of power transmission by electrical means, they would long ago have established a system of terms and values concurrent with those employed in dynamics." (Richards on Power Distribution, p. 94.) On the contrary, all reputable manufacturers of dynamos and electric motors constantly use these terms and the instruments for determining such values in all cases of investigation. Electric lamps, electric motors and dynamos as compared by their values in watts. And the watts are readily obtained by placing a voltmeter and ammeter to the circuit of the machine and reading their deflections.

$$\text{Then volts} \times \text{amperes} = \text{watts, and } \frac{\text{watts}}{746} = \text{horse-power.}$$

Now let us apply these instruments and others to an illustrative case. We will take for our plant a 100 h. p. steam engine driving a dynamo of approximately the same h. p.; a conductor extending to and from between dynamo and an electric-motor at a distance of say, one mile; the electric-motor doing work like pumping water, for instance. Having indicated our steam engine, we find 100 h. p. is applied to the dynamo belt when the dynamo is at work. Now introduce in the circuit an ammeter, and joining the binding posts of the dynamo the circuit of a voltmeter. At the same instant these two instruments read 30 amperes and 2262.9 volts. Then, $\frac{30 \times 2262.9}{746} = 91$ h. p. This shows an efficiency of $\frac{91}{100}$; because 91 h. p. is the electrical

output of the dynamo in return for the 100 h. p. expended upon it. Having previously measured the electrical resistance of the conductor between the dynamo and motor and found it to be one ohm, then the formulæ, $\frac{1 \text{ ohm} \times 30^2 \text{ amperes}}{746} = 1.2$ h.p. expended in forcing 30 amperes through the one ohm resistance of the conductor. Now we will have a voltmeter and ammeter at the motor, and make reading of them at the same moment of reading those at the dynamo. The readings are 30 amperes and 2232.9 volts. Then, $\frac{30 \times 2232.9}{746} = 89.8$ h. p., which is the electrical energy applied to the electric-motor. Having found by measurements well known to the hydraulic engineer, that the actual power exerted on the pump by the electric-motor is 81.71 h. p., we find that $\frac{81.71}{100}$ expresses the commercial efficiency of the plant. We also find $\frac{81.71}{89.8} = 91$, the percentage of conversion made by the motor of electrical energy into mechanical power.

This is not at all a hypothetical case, but rather one capable of demonstration. It has been said, with truth, that dynamo-electric machines are the most nearly perfect known converters of modes of energy. By dynamo-electrical machines, I mean both generators and motors.

You ask how are such machines made? What are the requirements? Mechanical generators of electricity are machines for moving wires between the poles of magnets for the production of currents of electricity in the wires, which currents are conducted through wires connected to the dynamo wires to places where utilized. Electric-motors are machines in which wires are moved between the poles of magnets by currents of electricity passing through the wires, and which thus furnish power for mechanical purposes. In both cases the losses are due (1) to friction of the moving parts at the journals and commutators; (2) the electrical resistances of the wires which are part thereof; and (3) to the production of local currents in the masses of metal forming the parts of the machines; which local cur-

rents are not available in the working circuits of the machines, and are technically called Foucault currents. These are the principal sources of loss. There are others, but they need not be considered here. The laws governing these losses are well understood, and the means of prevention are well defined, so that suitable construction will reduce the losses from these causes to the minimum.

The early motors were constructed after the following three plans: (1) A stationary permanent magnet, or magnets; a rotary, or a reciprocating, electro-magnet or magnets, as an armature; and an arrangement called a commutator, by which the direction of the current of electricity was reversed in the coils of the armature electro-magnet at the moment of passing the poles of the stationary magnet. (2) The same parts, except that the permanent magnet was replaced by an electro-magnet. (3) Stationary electro-magnets and masses of iron which were rotated in the neighborhood of their poles, and a commutator by which the current was reversed at the moment of the passing of the masses of iron past the poles of the magnets. Innumerable changes were rung upon these parts, but the three named are the typical ones. What were their faults? Let us see. With each change in the direction of the primary current of electricity secondary currents were generated in the masses of metal which were surrounded by the coils of wire. With each reversal of magnetism in the cores or masses of iron like currents were generated in them. These currents were not of the least use, and simply represented the power wasted in producing them. The currents are called *Foucault* currents (after Foucault), and have been the bane of the dynamo and motor inventor. These losses were very serious, and represented in many cases over eighty (80) per centum of the power-equivalent of the current supplied to the motors. The existence of Foucault currents was either not understood or was ignored. All sorts of lever devices, such as are affected by perpetual-motion men in the effort to cheat Nature, were tried, but without success. Each lever addition made so much more friction to be overcome. In the effort excessive lengths, and consequently excessive electrical resistances, of wire were added, thus increasing the amount of electrical

energy required. The electrical energy requisite being as C^2 R. Of course resistance cannot be altogether avoided, but it is evident that it should be made as small as is practicable.

With the invention of the Gramme machine in 1869 was ushered in the new era of electrical appliances. All the dynamos and electrical motors of the present day, which are of any commercial value, are modifications of the Gramme dynamo. Therefore a typical description of it will serve with which to begin the consideration of the practicable electro-dynamic machines which are so fast coming into use.

The Gramme machine consists of a stationary electro-magnet between the poles of which its armature is rotated. This armature consists of a ring of iron on which is wound the coils of insulated wire in which the currents of electricity are generated. On the shaft of the armature an instrument called a commutator is mounted. The shaft is passed through the ring concentrically with its periphery. The iron core of the ring is made up of a coil of iron wire, so as to avoid the objectionable Foucault currents, it having been experimentally found that dividing the mass of iron and insulating the parts from one another decreased these currents. The coils of insulated copper wire are wound upon the iron ring-core by threading them through and through the ring and parallel to the shaft, but perpendicular to the direction of the winding of the iron wire. At predetermined intervals loops are run from the copper coils to the sectors of the commutator, a loop to each sector. The commutator is a cylinder of metal divided into sectors which are insulated from one another except through the loops and wires of the armature. At diametrically opposite points on the commutator, and on a line midway between the poles of the stationary magnet, springs press on the commutator and serve to conduct the currents generated in the armature coils to the external circuit. This machine is perfectly reversible—that is to say, if mechanical power be applied to its pulley it will generate electricity. It is a converter of mechanical energy into electrical energy. Or apply a current of electricity to its wire coils and it is an electric motor, a user of electrical energy, a converter of electrical energy into mechanical energy.

Many varieties of the Gramme machine have been made and called by various names, as have been made many varieties of Watt's steam engine. The variations have been in the form and mass of the stationary magnets; the length, diameter and thickness of the armature core; the substitution of other divided forms of iron in the core; changes in the manner of winding the insulated copper wires on the armature core, etc., in endless number.

It has been found theoretically, experimentally and practically that the Gramme machine is vastly improved, by making the armature core of thin disks of iron instead of the iron wire; one reason is because in that way the iron is better presented to the inductive action of the stationary magnet. By this construction the wasteful *Foucault* currents are very much decreased. Consequently upon this the length of wire needed on the machine is much decreased, and with a corresponding decrease in its electrical resistance, and therefore in the waste of power. The actual improvements have been in the substitution of properly proportioned amounts of iron in the cores of the stationary magnet and armature for great lengths of copper wire. The writer has made dynamos which had less length and weight of wire on each of those used for the production of thirty arc lights than were on one of the early Gramme machines used for the production of one light. Such improvements have increased the efficiency of dynamos and motors from less than 40 per cent. to over 90 per cent., so that while in 1873 scarcely 16 per cent. of transference of power by means of electricity could be effected, now it is possible to transfer by this means upwards of 80 per cent.

Time is too limited, neither is it necessary here, to name a long list of illustrations of the practical workings of electrical transmission. They are enumerated in the many publications upon the subject. See *Du Moncel's Electricity as a Motive Power; Kapp's Electrical Transmission of Energy; Luce's Electric Railways and the Electrical Transmission of Power; Martin & Wetzler's The Electric Motor and its Applications; Urquhart's Electric Motors;* the *Proceedings of the National Electric Light Association* a month ago in Philadelphia; and the electrical serial publications, such

as the *Electrical World*, *Electrician*, *Electrical Review*, etc. We will only consider briefly a few of the possible and practicable applications of this mode of power transmission. Having a dynamo and motor of 90 per cent. efficiency each we can transmit power within their capacity with only the further loss due to the electrical resistance of the conductor joining the two. As this resistance varies directly as the length of the conductor and inversely as its cross section, it follows that the loss from that reason can in all cases be made as small as may be practicable when the cost of the conductors is considered, compared with the worth of the power saved or lost. One mile of conductor of round copper 0.460 of an inch in diameter, weighing 3,375 pounds per mile, and having a resistance of 0.259 ohm per mile, now costs in San Francisco about $650. If 100 electrical horse-power divided as follows,

$$\frac{2487 \text{ volts} \times 30 \text{ amperes}}{746} = 100 \text{ h. p.}$$

was to be transmitted over this mile of conductor the loss would be 0.312 horse-power, as per this formula:

$$\frac{30^2 \text{ amperes} \times 0.259 \text{ ohms}}{746} = 0.312 \text{ h. p.}$$

Suppose that we take a No. 6 wire, weighing 419 pounds per mile, having a resistance of 2.08 ohms per mile and costing $80, then the loss would be 2.51 horse-power, as per this formula:

$$\frac{30^2 \text{ amperes} \times 2.08 \text{ ohms}}{746} = 2.51 \text{ h. p.}$$

The question then is shall we spend $570 more per mile in cost of plant that we may save over two horse-power per mile continually thereafter? Where power is abundant and cheap, No; where power is limited and dear, Yes.

Dynamos can be made of any size up to 1,000 horse-power or larger. Motors can be made of any size, from that of a mouse-power up to a thousand horse-power or more. They weigh say 50 or 60 pounds per horse-power, and at present sell for big prices.

What are their practical applications? For one, I imagine a central station in a city and where steam engines and boilers are located, having a capacity of say 1,000 horse-power, with the best approved appliances for the economical production of power, and dynamos of high efficiency producing electricity which is sent out over the city to elevators, street railways, factories, printing offices, machine shops, sewing machines, dentists, jewelers, pumps, and innumerable users of power in small quantities, and sold at from $100 to $200 per year per horse-power capacity of motor. How much cheaper for the user than to produce steam or gas power for himself, and how profitable to the producer. As in the case of all power plants much more horse-power is paid for than is used, because each user pays on the basis of his maximum requirements, while he seldom draws so heavily on his supply. It has been found in the several electric power stations in the East that not half the power is used at any one time as is being paid for, and that the users are receiving the power they need at far less cost than before—conveniently, and almost luxuriously in point of utility, cleanliness, convenience and safety.

For example: A waterfall located where its power cannot be made directly available can run a water-wheel belted to a dynamo, from which wires run to electric motors located where power is desired, and from the motors the motion needed is obtained. This can be done on any scale within the power capacity of the waterfall, even to many hundreds of horse-power.

Another example: At a waterfall or other power station have dynamos connected by wires running along a railway with motors on cars or dummies, for the purpose of carrying passengers and freight.

Another example: At a waterfall in the mining regions locate a dynamo, and from it run wires to motors used for drilling, pumping, hoisting, hauling, crushing, etc., and located at the most desirable places.

Electric lighting companies may utilize their power plants during the day-time by erecting circuits and operating motors thereon at the various manufactories and users of power in their towns and cities.

The examples can be made innumerable. Enough has been said to show the almost endless applications of these power methods.

Compare the loss in power absorbed by moving the cables alone in the cable-railway systems with the loss from resistance of electric conductors capable of performing the same service. Authorities state the cable losses at from 68 to 90 per cent. of the total power. The losses due to dynamo, conductor and motor can easily be made less than 30 per cent. The loss from the cable is the same, whether one or many cars be moved. The loss when only one car is moved is almost 100 per cent. But with an equally long electric line the loss with only one car on the line need not be two horse-power. Electric railways are being run all over this country and Europe. Crude in their beginnings, they are fast being improved.

Broadly speaking, there are two modes of transmitting power by means of electricity. They are called respectively the "multiple arc," or "parallel," and the "series." By the former the current of electricity from the generator is divided so that a part only goes to each electric motor; and that part is the same in proportion to the whole as the power of the motor bears to the total power. The electrical energy is supplied at a constant electro motive force expressed in volts, and is utilized in parts of the current expressed in amperes. Then the power of each motor is expressed as follows: $n\mathrm{C}\times\mathrm{E}$, less the amount of energy absorbed by the motor in overcoming the friction of its moving parts, the Foucault currents, and its electrical resistances. This last value is $\frac{{}^{n}\mathrm{C}^{2}\,\mathrm{R}}{746}$ C representing the current used by the motor, in amperes, R the resistances of the motor in ohms; and 746 the number of watts per horse power. The foregoing method is also called the "constant potential" one. That is to say, its electrical energy is furnished at constant pressure.

The "series" mode is commonly called the "constant current" one. It is so denominated because the electric current is furnished to the motors at a constant number of amperes; and these amperes flow through whatever number of motors may be

upon the circuit of a dynamo in serial order—one after another. Each method has its advantages which make it better adapted to one or others of the conditions inseparable from practice. The consideration of the details of the two methods I defer for another paper.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

FACTS CONNECTED WITH THE EXPLOSION OF A CARGO OF DYNAMITE ABOARD THE SCHOONER "PARALLEL," WHILE TRYING TO CLEAR THE ENTRANCE TO SAN FRANCISCO HARBOR.

BY L. J. LECONTE, MEM. TECH. SOC.

Read July 1, 1887.

The schooner "Parallel" was a sailing vessel of moderate dimensions, being 142 tons register and having a capacity of about 350 tons. Her crew consisted of seven men, all told. For ballast she carried 10 tons of pig iron and 10 tons of coal in sacks. Over this was laid 10,000 feet of hardwood lumber. Next in order came the cargo proper, which comprised 82,600 pounds of dynamite of three varieties, namely, Giant Powder—No. 1, 14,250 pounds; No. 2, 43,350 pounds; and Judson Powder, 25,000 pounds. This material was packed in wooden boxes containing 50 pounds each, and was carefully stowed away amidships. In addition she also had in her hold some 50 cases of coal oil and 20 barrels of machine oil, and 10 tons of baled hay. Her deck load comprised one salmon boat, water casks, and some miscellaneous matter.

Giant Powder, No. 1, is a mixture of nitro-glycerine with some absorbent, formerly the well-known kieselguhr, but now most generally its place is taken by a fair quality of wood pulp. The percentage of oil is estimated at 75 per cent. This powder is water-proof.

Giant Powder, No. 2, is supposed to contain wood pulp, nitrate of soda, and say 40 per cent. of nitro-glycerine. This powder is not water-proof.

Judson Powder has the same ingredients as ordinary black blasting powder, with say 5 per cent. of nitro-glycerine added, and of course is not water-proof.

On January 15th, 1887, this vessel at about 9 o'clock P. M., while clearing the port of San Francisco, became unmanageable and began to drift ashore towards the rocky point near the Cliff House. The crew naturally became alarmed and finally took to the boats and left the schooner to her fate. About 9:15 P. M. she went ashore nearly 800 feet north of the Cliff House and grounded on some outlying rocks. She soon stove in her bottom and settled down hard upon the reef, sitting nearly upright with all sails set and sidelights burning. A light was burning in the cabin when the crew deserted her. Heavy seas prevailing at the time, soon deluged her decks and filled her cabin full of water. Her deck load and water casks were washed overboard and drifted ashore. Persons on shore managed to get aboard the schooner, but finding no one there returned and reported the facts. Two watchmen were placed on the bluff above the wreck with orders to burn blue lights for assistance. Parties walking along the beach picked up fragments of broken dynamite boxes with trade-marks thereon. The schooner bumped upon the rocks from 9:15 P. M. to 12:34 P. M., or say 3¼ hours, when her cargo of dynamite exploded with terrific force, damaging all the houses within a radius of a mile and strewing the fragments of the vessel and cargo for a distance of half a mile around the site of the wreck.

MECHANICAL EFFECTS.

The schooner was absolutely and completely annihilated; not a vestige of the vessel remained to mark the spot where she lay. Fragments of shivered timbers and wire rigging lay scattered over the adjoining country for a mile; one piece from her bows, weighing some 3,000 pounds, landed on the beach abreast of the Pavilion, distant 2,300 feet from the wreck. Nothing of her cargo was found save the pig iron ballast, which was scattered

all over the entire neighborhood, pieces weighing 50 to 100 pounds being found at a distance of 2,500 feet from the site of the explosion. This fact should be remembered.

At the time of the explosion the schooner was laying close up against a large outlying rock, averaging 15 feet high, 30 feet wide and 60 feet long, containing say 1,000 cubic yards of solid highly metamorphic sandstone, weighing say 165 pounds per cubic foot, or something like 2,000 tons of solid rock. This rock was completely demolished and wiped out of existence; a smooth, gravelly beach now covers the site.

A portion of the rocky cliff abreast of the schooner had a large piece gouged out to a depth of eight feet, and extending some distance up the hill.

The two watchmen standing guard on the brow of the cliff were severely stunned by the explosion. One was blown off his feet and up the hill a distance of 200 feet, while the other was blown to a distance something less; both men had a miraculous escape. The large outlying rock intervening between them and the blast undoubtedly saved their lives.

Damage to houses.—The mechanical effects on the neighboring houses was something extraordinary in character, and are well worthy of record. First we have the Cliff Cottage (see map). This is a two story frame building distant 630 feet from the blast, and 100 feet above. The entire building was driven bodily one foot toward the roadway. Every window and outside door was driven inwards with great violence. Nearly all the plastering on the ceilings and side walls was blown off and into the rooms, mingling with the broken window-glass all over the floors. The lighter furniture was upset by the carpets being blown up off the floors, while the heavier pieces were twisted round out of position. The lighted lamps were blown out. Quantities of soot from the chimneys was blown down and into the rooms. The most remarkable feature observed in this place, and which struck me at the time as extraordinary, was the fact that where a window on the side of the house next the blast came opposite to an inside partition wall, there we find the force of the blast so violent that after crushing in the window it con-

tinued right across the room a distance of twelve feet or more, and actually blew a hole clear through the partition wall and of the same size and shape as that of the window through which it entered. Of course the 2″ x 3″ studding was left *in situ*, but all the laths and plastering on both sides was blown out completely, making a clear and sharp outline. All around the margin of this hole, as well as against the face of the studding, was a perfect fringe of long needle-like fragments of glass driven into the plastering and woodwork with great force and penetration.

The Cliff House. — This is a two and a half-story frame building, distant 795 feet from the schooner, and 85 feet above it. Here the mechanical effects of the blast were almost identically the same as those seen at the Cliff Cottage. The damage was greatest of course at the north end of the house next to the blast, where the entire sidewall of the kitchen was blown in; but all the windows and outside doors were burst inwards with great force, in some instances splintering the doors into small fragments like kindling wood.

The Sutro House.—This is a one-story frame building with a high basement, situated 1,350 feet from the blast and 200 feet above. Intervening between the blast and this house is a very high picket fence (25 to 30 feet), which is used as a wind break. The same general facts and features were found to exist here as elsewhere, bu tthe effects were much less violent. The shock struck the house on the corner; all the doors and windows were stove inwards on the front and north side, while in the south end and rear the same facts were true but somewhat less in extent. The frescoed ceilings and side walls were all badly cracked and blown inwards; but taken as a whole this house was much less damaged than the Cliff House. The outbuildings near the Sutro House suffered pretty much the same damages, though apparently to still less extent, for the reason, I fancy, that the window-sashes contained small panes of glass, and therefore had stouter framework to resist the outside pressure successfully. Another feature worthy of note, is that next to the Sutro house, on the west, are situated a lot of light terra

cotta statuary, which were under shelter of the Cliff Cottage, and therefore not exposed to the blast direct; as a result they escaped intact.

Large Glass Conservatory.—This building was fairly exposed to the blast, and was distant 1,625 feet from and 192 feet above the schooner. It was of course badly smashed to pieces. The blast crushed in nearly all the panes of glass, seemingly on all sides alike, except in the turret on top of the building, which being composed of small panes set in stout sashes was naturally hardest to crush in and therefore remained intact.

Seal Rock House.—This building was distant 2,000 feet from the origin of the blast and about 24 feet above. One gable end was situated close under the rocky cliff behind the hill, and therefore did not suffer as much damage as other houses more distant. The end of the building next the cliff was nearly uninjured, while the windows towards the farther end and facing the roadway, were blown in and the ceilings and side walls badly cracked, but nothing more. One would naturally think that this building—being close in behind a hill 200 feet high and entirely sheltered from view of the blast—would have escaped entirely, but such was not the case.

The Large Pavilion.—This was a three-story frame building distant 2,300 feet from the blast and 24 feet above. Much more damage was done here than at the Seal Rock House. The windows and doors on all sides were stove in, and the ceilings and side walls also badly cracked and plastering blown inward over the floors, more particularly on the side next the roadway. Pieces of pig iron weighing fifty pounds were found in the back yard next to the bluff. By reference to the map it will be seen that this building was also behind the hill.

Park and Ocean R. R. Depot.—This is a low one-story building, distant 2,600 feet from the blast and 24 feet above. Like all the others in this vicinity the building is under shelter of the high hill. The damage done here was little or nothing, and examination showed that this fact was doubtless due to the open-work nature of the construction, which readily admitted of

rapid adjustment between the inside and outside pressures. If it had been a closed structure, like the adjoining building mentioned below, the damage would have been equally great.

Boarding House and Exchange.—These two frame buildings are opposite the depot on the east side and immediately across the way. They are about 2,700 feet from the site of the blast and 24 feet above, both being under shelter of the same hill before mentioned. These buildings were both badly damaged; the doors and windows in front of the stores were crushed in with great force, locks and hinges being torn off the doors. The plastering was also blown inward from the ceilings and side walls, like the other houses nearer the blast. The violence of the shock at this place was much more marked than one would at first sight suppose, and what made it particularly interesting was the strong contrast in mechanical effects as compared with the slight damage done to the depot across the way.

As above mentioned, the true reason lies in the fact that these buildings were closely shut at the time of the explosion, and the sudden increase in outside pressure could only adjust itself by crushing in the outside doors and windows.

Merchants' Outer Telegraph Station. — These buildings were distant 1,000 feet from the origin of the blast and situated 200 feet above. By inspecting the map it will be seen that the rocky bluff abreast of the schooner protected these buildings entirely against any *direct effect.* As a result, the houses here suffered less damage than would have been the case had the conditions been otherwise. They experienced exactly the same phenomena as regards the bursting in of all doors and windows, etc., as above described in the case of other houses.

United States Life Saving Station.—This building is situated 3,675 feet away from the origin of the explosion and about 25 feet above. Here we found the mechanical effects to be least of all, consisting simply in the breaking of a few panes of window glass and in blowing out the lighted lamps.

Deductions which may be drawn from the mechanical effects.—In looking over the field of destruction I was soon impressed with

the marked distinction between the characteristic features of the damage done to houses close to the blast as compared with those which were more remote; that is to say, all the houses damaged showed unmistakable evidence of being subjected to a sudden and violent compression of the surrounding atmosphere, so great in intensity as to burst in the windows and outside doors; but the houses nearer the blast, in addition to this general effect, common to all, experienced a powerful thrust on the side next to the explosion, notably the Cliff Cottage, distant 630 feet, which was driven bodily one foot towards the roadway. At the Cliff House, distant 795 feet, the thrust effect was somewhat less marked, but still very decided. Next we have the Sutro House, distant 1,350 feet; here the thrust effect on the side next the blast was much less pronounced—we might say relatively quite feeble yet noticeable. Finally, then, we have the large glass conservatory, distant 1,625 feet, where there seems to have been an entire absence of evidence as to the existence of any thrust effect on the side of the house facing the blast. Now, then, it would seem reasonable to suppose, from the above facts, that the radius of the thrust-effect, in this particular neighborhood, was somewhere between 1,350 and 1,625 feet in length. Beyond this limiting radius the damage done to houses seems to be such as is due simply to a universal compression of the surrounding air, and therefore the mechanical effects were the same on all sides alike. The reader will have noticed probably that the houses on the beach road, distant 2,300 feet, and completely sheltered behind the high hill, were nevertheless considerably damaged by the blast. This fact is quite remarkable, and seems to show that a spherical wave of compression transmitted through the air will pass an intervening obstacle and re-establish its sphericity behind the same so rapidly that the obstacle really affords little or no shelter.

Probable causes which led to the explosion.—Several theories have been advanced by as many different men, all of whom seem to base their opinions more or less on the pure assumption that the schooner took fire and subsequently exploded. It seems to me that there is no necessity for such an assumption as conflagration or any other outside hypothesis. The two

watchmen on the cliff near the blast, as well as other witnesses, refute the idea of there being any conflagration aboard the schooner, and state that the ship's hold and cabin were full of water soon after she struck on the rocks, and, furthermore, that solid seas swept her decks with nearly every swell that came in from the bar.

Now let us simply consider the existing facts of the case. In the first place the schooner had ten tons of pig-iron in the bottom of her hold; immediately over this was the cargo of dynamite. It follows as a necessary consequence that when the vessel struck on the rocks her bottom was stove in and the pig-iron was forcibly driven up into and mixed with the bursted boxes of dynamite, fragments of which came ashore before the explosion, having the trade marks thereon intact.

Here now we have a schooner bumping and grinding to pieces on the rocks, with ten tons of pig-iron in her hold all besmeared with dynamite. It is a fact well established that iron work of any kind besmeared with nitro-glycerine will explode when roughly handled. The chief lesson therefore to be learned from this accident would seem to be, that iron work, besmeared with dynamite, will also explode when roughly handled even if submerged in water.

LIFE SAVINGS STATION
P.&O. R.R. DEPOT
EXCHANGE
BOARDING HOUSE.
PAVILLION
SEAL ROCK HOUSE
LOW WATER LINE
CONSERVATORY
PALTRO HOUSE
PICKET FENCE
HIGH
ROAD OF THE BEACH
CLIFF HOUSE
POINT LOBOS ROAD
CLIFF COTTAGE
SHED
MERCHANTS OUTER TELEGRAPH STATION
SCHF PARALLEL

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME IV.—APRIL—DECEMBER, 1887.)

MINUTES OF MEETINGS.

REGULAR MEETING.

April 1, 1887.

President Mendell in the chair.

Minutes of preceding meeting read and approved.

The committee reported having counted the ballots for N. S. Keith and M. G. Wheeler, both of whom were elected.

H. T. Compton read a paper on "A New Method of Differentiation."

N. S. Keith read a paper "On Transmission of Power by means of Electricity."

REGULAR MEETING.

May 6th, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

June 3d, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

July 1, 1887.

In the absence of the President and Vice President, Marsden Manson was chosen Chairman.

L. J. LeConte read a paper on "Facts connected with the Explosion of a Cargo of Dynamite aboard the Schooner *Parallel* while trying to clear the entrance of San Francisco Harbor."

REGULAR MEETING.

August 5, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

September 2, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

October 7, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

November 4, 1887.

There being no quorum the meeting was not called to order.

REGULAR MEETING.

December 2, 1887.

The President and Vice-President both being absent, Mr. Manson was chosen as Chairnam.

The Chairman called attention to Article 11 of the By-Laws, relating to the selection of a Nominating Committee.

He also made a suggestion relating to the appointment of a Technical Secretary, who should be salaried, and who should collect matter relating to the different branches of the engineering profession, and publish it once a year.

Mr. d'Erlach moved that the Chairman appoint, for the Society, members of the Nominating Committee to select officers for 1888.

The Chair appointed Messrs. Burr, d'Erlach, Gutzkow, Von Geldern and Percy.

Mr. Manson suggested that in each branch of the Society there may be some technical investigation which would be specially beneficial to the Pacific Coast, and that, through the Technical Society, we would have an opportunity of calling the attention of capitalists to such matters.

The Chairman also suggested that in view of the deaths of D Jennsen, Milo Hoadley and Wm. Ashburner, members of the Society, a committee should be appointed to draft appropriate resolutions.

Mr. Percy thought that these matters should be brought before the annual meeting in its President's address.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME V.—JUNE, 1888.)

PRACTICAL APPLICATIONS OF IRON AND CONCRETE TO RESIST TRANSVERSE STRAINS.

BY G. W. PERCY, MEM. TECH. SOC.

Read January 6, 1888.

Concrete composed of broken stone, fragments of brick, pottery, gravel and sand, held together by being mixed with lime, cement, asphaltum or other binding substances, has been used in construction to resist compressive stress for many ages.

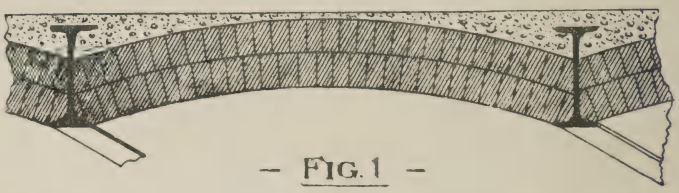
The Romans used it more extensively than any other material, as the great masses of concrete, once the foundations of large temples, palaces and baths, the domes, arches and vaultings still existing, together with the core or interior portions of nearly all the ancient brick-faced walls found in Rome, testify.

In modern times, however, until the introduction of Portland cement, concrete has been used generally for no other purpose than for footings of walls and foundations underground.

With the introduction of Portland cement, concrete construction has taken a more prominent part, and has advanced regularly with the perfection and general use of that valuable material, until not only foundations but the entire walls of buildings, piers and arches, floors and roofs, have been constructed

of it, while moulded trimmings and ornamental blocks are cast of it and set in walls similar to cut stone.

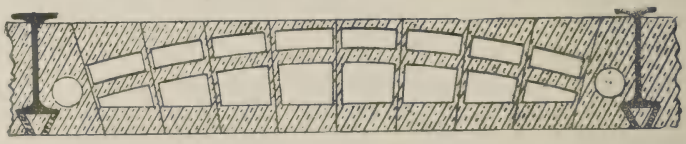
The cheapness, in most places, of the aggregates composing concrete, together with the fact that mixing and placing may be done with cheap and unskilled labor under intelligent direction; its enduring and its fire-resisting qualities, together with its great compressive strength, all recommend it for use in permanent constructions. Its low tensile strength and liability to fail without giving warning, under tensile or transverse strain, has hitherto prevented its use for beams, lintels or floors, unless supported by iron beams or other means.



— FIG. 1 —

For thirty years or more, so-called fire-proof floors have been constructed in England, and some parts of this country, by means of rolled iron beams, with concrete or brick arches turned from the top of the lower flanges, and leveled over the top, as shown in Fig. 1.

This method of construction fulfilled all requirements of strength and safety, except that for which it was especially designed: protection from fire. When subjected to the test of hot fires, its failure was conclnsive and the cause apparent. The



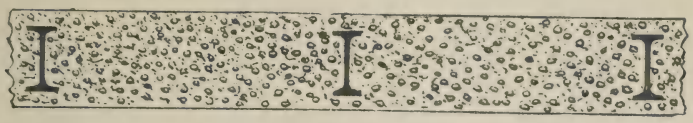
— FIG 2 —

lower flanges of the iron beams, as the tie member, and the most vital, being exposed directly to the heat, expanded with it, causing the beams and floor to sag with every increasing degree

of heat; at the same time it lost its tensile strength, and failed utterly.

The next step, and the one generally practiced at this time, was to encase the lower flanges of such beams with terra-cotta, plaster-of-Paris or other non-conducting materials, as Fig. 2.

Among other methods devised was that shown in Fig. 3, where the beams are entirely encased in concrete, extending two or more inches below and above the beams.



– Fig 3 –

While contemplating this method of fire-proof construction some twelve years ago, in England, the well-known inventor, Thadeus Hyatt, was led to consider if the iron used in the lower flanges of the beams could not be so united to the concrete as to work in unison with it and form a compound beam or girder, the iron to serve only as the tie or tensile member, while the concrete formed the compressive member and connecting web.

Mr. Hyatt made many experimental beams, with the iron introduced in a great variety of ways—as straight ties, with and without anchors and washers; truss rods in various forms; flat pieces of iron set vertically and laid flat, anchored at intervals along the entire length. These experimental beams were tested and broken by David Kircaldy, of London, and the results published by Mr. Hyatt in a neat form for private distribution, in the year 1877, for the use of which the writer is indebted to P. H. Jackson, a member of this society, who, in a paper read before it on August 10, 1884, gave many of the results of Mr. Hyatt's experiments in detail, together with some of his own. The final conclusion of Mr. Hyatt, well demonstrated by his tests, was that iron could be perfectly united with concrete, and could be depended upon under all conditions for its full tensile strength.

The method Mr. Hyatt fixed on as the best was to use the tie iron, as thin vertical blades placed near the bottom of the concrete beam or slab, extending its entire length and bearing on the supports at both ends; these vertical blades to be anchored at intervals of a few inches by round wires threaded through holes punched opposite each other in the vertical blades, thus forming a skeleton or gridiron, as shown in Fig. 4.

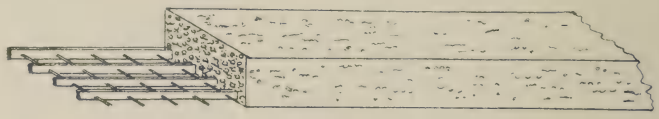


FIG. 4

This combination effected a saving of about two-thirds of the iron required in the method shown in Figs. 1, 2 and 3, as the entire web and top flange was dispensed with, the same amount of concrete serving the double purpose.

Although this valuable discovery was given to the world ten years ago, it has not been generally adopted or extensively used either in this country or in England, at least such use has not come to the writer's knowledge, and this not from any failure in the application or defect in the system, but from the general disinclination to adopt new and novel methods of construction, however meritorious they may be.

For several years past Mr. Jackson, of this city, has experimented with this system, and with variations of his own suggestions, the testing of which has been witnessed by the author with great interest. The results of three of such tests will be given in detail from notes made at the time. The first test was made on January 16, 1884, on a tile of side-walk lights $12 \times 24''$ and $1\frac{5}{16}''$ thick. This tile consisted of four rows of bull's-eye glass, ten in each row, with five blades of iron, $\frac{1}{8} \times \frac{5}{8}$ inches, extending lengthwise, and eleven wires of steel $\frac{3}{32}$ inches in diameter, threaded crosswise. The concrete consisted of one part Portland cement to one part fine screened gravel or coarse sand, and had been made forty-one days. This was tested by being supported on one-inch bearings at each end, leaving

1 foot 10 inches between bearings. The weight was suspended from a steel bar, bedded in plaster, across the center of the tile.

The deflection was accurately measured at frequent intervals as the load was applied, and recorded in 64ths of an inch.

TEST OF HYATT LIGHT SLAB, NO. 1.

Load.—Lbs.	Deflection.—64ths.	Remarks.
885	2	442 lbs. to $\frac{1}{64}$.
1198	5	
1376	6	$138\frac{1}{2}$ lbs. to $\frac{1}{64}$.
1545	7	
1717	8	
1906	10	
2017	12	
2150	13	73 lbs. to $\frac{1}{64}$.
2210	14	
2300	16	Fine crack observed.
2350	17	
2405	18	
2468	19	$37\frac{1}{2}$ lbs. to $\frac{1}{64}$.
2531	21	
2600	24	
2710	29	22 lbs. to $\frac{1}{64}$.
2750	—	Broke by crushing the concrete and glass near the center bar, none of the iron rods breaking.

Fine cracks were first discovered when the load was about 2,300 lbs., and the deflection $\frac{1}{4}$ inch. These cracks were directly under the cross-wires near the center. The center load of 2,750 lbs. is equivalent to double the amount distributed, or 3,000 lbs. for each square foot of surface between bearings, or a safe load of 500 lbs. per foot, with factor of safety of 6.

Two tests on these tiles, with quite similar results, satisfied the writer of the strength, and he has not hesitated to use them in practice. The sidewalk lights around the Firemans Fund Insurance Co.'s building are constructed in this manner.

The next illustration of the strength of this combination of iron and concrete was recorded on Jan. 19, 1884, at the Industrial Iron Works in this city, where a slab 4 ft. 6 in. by 4 ft. 6 in. by 3″ thick, made by Mr. Jackson, was tested. This slab had 19 wrought iron blades $\frac{1}{8}$ x 1″ placed $2\frac{3}{4}$″ on centers extending through the slab in one direction and near the bottom,

threaded by nine wires $\frac{1}{4}$ in. diameter six inches apart. Concrete composed of one part Portland cement to two of sand, and 62 days old, supported by bearing 3 inches at each end, or at ends of blades, and loaded with pig-iron. Deflection noted in 32ds of inch.

TEST NO. 2.

Load.—Lbs.	Deflection.—32ds.	Remarks.
9,047	3	Or 3016 lbs. to $\frac{1}{32}$.
12,134	5	
15,167	7	1531 lbs. to $\frac{1}{32}$.
18,234	9	
21,111	10	Fine cracks first observed.
24,140	12	1442 lbs. to $\frac{1}{32}$.
26,885	14	
29,554	16	
32,747	18	1353½ lbs. to $\frac{1}{32}$.
35,206	20	

36,375 broke by parting all the iron blades on the line of wire nearest the center; the concrete did not crush.

In loading the pig-iron care was taken not to bond it by laying any bars in the direction of the length of the blades, and therefore the pile assumed somewhat a pyramidal form near the top, thus throwing more weight toward the center of slab. A fine crack was first observed when the load was about 20,000 lbs. and the deflection $\frac{1}{3}$ in. This breaking load was equal to 2,000 lbs. per sq. ft., or safe load of 333 lbs per sq. ft., with factor of safety of 6.

But one other test of this method will be given, and this was made on the 31st of August, 1885, at the Industrial Iron Works.

Mr. Jackson had prepared a beam 7 x 14 inches in section and 10 feet 6 inches long. Near the bottom were seven vertical blades of iron extending the entire length; three of these were $\frac{1}{4}$ x 1 inch and four were $\frac{1}{8}$ x 1 inch, with $\frac{1}{4}$-inch wires threaded through every three inches. Near the top were bedded two cast-iron rope moulding bars, to assist the compressive strength of the concrete (an unnecessary precaution). The concrete at top and bottom, for about four inches, was one part cement to one of sand; center portion, one of cement to two of sand. The

beam was supported by 9-inch bearings at both ends, thus leaving it 9 feet in the clear between bearings. It was loaded with pig-iron piled across the beam, and bonded only with thin hoop-iron.

Several architects and engineers were present at this test, among others Professor Soulé, of the State University.

The writer had received from Mr. Jackson, a day or two before, all the data in reference to the beam, including its age (about five months). He had estimated its strength based on a tensile strength of 60,000 pounds for hoop-iron, and expressed his confidence to several gentlemen that the beam would require about 27 tons to break, and that it would deflect an inch before breaking.

The result shows nearer than could be expected from calculation on the strength of any materials. Deflections are here noted in 32ds of an inch.

TEST No. 3.

Load.—Lbs.	Deflection.—32ds.	Remarks.
20,695	2	10,363 lbs. to $\frac{1}{32}$.
30,989	3	
33,589	4	1,187 lbs. to $\frac{1}{32}$.
36,045	8	
38,113	9	
40,056	12	630 lbs. to $\frac{1}{32}$.
42,062	16	Cracks first observed.
44,077	18	
45,678	21	
46,115	23	475 lbs. to $\frac{1}{32}$.
47,018	24	
47,996	26	
49,001	28	
50,054	30	369 lbs. to $\frac{1}{32}$.
52,052	36	
52,692	38	

53,654 broke by separating all the longitudinal blades on the line of one of the cross-wires near the center.

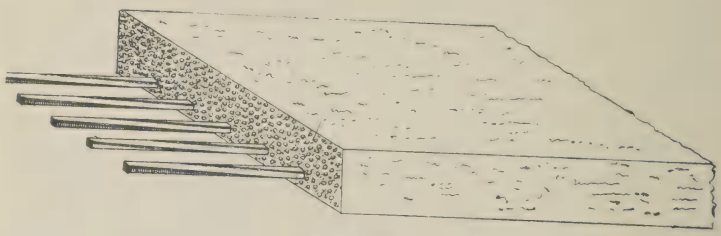
As will be seen by the above, the breaking load was 26.8 tons, and the deflection just before breaking 1.$\frac{3}{16}$ inches. Fine cracks were first observed at two or three of the wires near the

center when the load was about 42,000 pounds, and the deflection $\frac{1}{2}$ inch.

This breaking load of 53,654 pounds was equal to about 6,000 pounds per foot, or 1,000 pounds per foot with factor of safety of 6, which would evidently be a perfectly safe permanent load, as the deflection with 9,000 pounds was too slight to observe.

These experiments, together with the results of Mr. Hyatt's tests in London, should satisfy the most skeptical of the practicability of obtaining the full tensile strength of iron as a tie in concrete constructions.

The only objection to be urged against the practice of this method is, that by punching holes for the cross-wires the effective area of the tie metal is reduced by the amount of the diameter of the holes; and the labor of punching holes and threading wires is quite an item of the cost.



– FIG. 5 –

While these experiments were going on, Mr. E. L. Ransome, also a member of this society, and a very successful worker of concrete, was experimenting with a different method of obtaining the same result.

For several years he had used old wire cables as a bond in concrete walls, the irregularity of the wire ropes, caused by the twist of the strands, preventing the possibility of slipping when imbedded in concrete. This probably suggested to his mind the idea of twisting square bars of iron or steel and imbedding them in the bottom of concrete girders or flat slabs, as shown in Fig. 5.

It was evident that this method would be a great improve-

ment over that invented by Mr. Hyatt. The twist in the bar would cause it to be held securely at every point along its length, instead of at intervals of several inches; no metal would be wasted by punching holes, and no extra iron required for anchors. The labor of twisting the cold rods would be but a trifle, and the entire sectional area of the iron could be placed just where it would be most effective.

NOTE.—It has been demonstrated by experiments that the process of twisting the bars to the extent desired strengthens the rods instead of weakening them, as might be expected.

Mr. Ransome promptly patented his improvement, and since 1885 it has been used quite extensively in this city.

The results of two tests of this method, witnessed by the writer, will be given, together with several different applications he has made of it in practice.

The first test was of a slab 12 inches wide, 6 inches deep and 18 feet long, composed of one part Portland cement to five parts gravel and broken granite, with six twisted rods $\frac{1}{2} \times \frac{1}{2}$ inch imbedded near the bottom. When about four months old, the slab was tested by being placed on blocks bearing 12 inches at each end, leaving 16 feet between bearings; loaded uniformly with sand piled on planks laid across the slab. Such a slab without ties could hardly be expected to sustain its own weight. The deflection was noted in $\frac{1}{4}$ of an inch.

TEST No. 4.

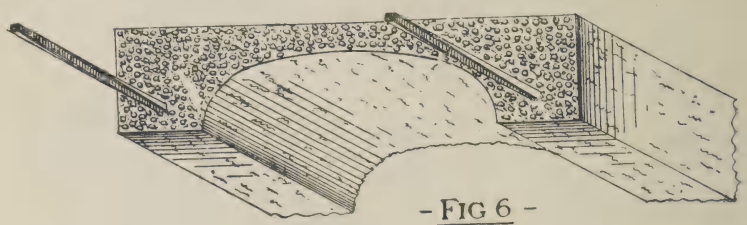
Load.—Lbs.	Deflection.	Remarks.
2,830	$\frac{1}{4}$	= 1,820 lbs. to $\frac{1}{4}$.
3,640	$\frac{1}{2}$	
4,450	$\frac{3}{4}$	
5,260	1	= 810 lbs. to $\frac{1}{4}$.
6,070	$1\frac{1}{4}$	
6,745	$1\frac{1}{2}$	
7,420	$1\frac{3}{4}$	= 630 lbs. to $\frac{1}{4}$.
7,960	2	
8,500	$2\frac{1}{4}$	
9,040	$2\frac{1}{2}$	= 540 lbs. to $\frac{1}{4}$.
9,580	$2\frac{3}{4}$	
9,985	3	= 405 lbs. to $\frac{1}{4}$.
10,390	$3\frac{1}{4}$	

10,660 broke by crushing the concrete about 2 feet from the

center. The slab split for some distance each side of the fracture near the center of thickness, or at the neutral axis.

The results of this test were given in a meeting of this society, as before stated, on August 10, 1884, at which time a fragment of the slab was exhibited, showing the position of the rods and the quality of concrete.

The result of the next test, although very interesting, cannot be given in detail, as it extended over several months, and was visited but two or three times by the writer. It consisted of a full-size section of a sidewalk arch and beam, as shown by Fig. 6, 5 feet 6 inches wide, 15 inches deep at beams and 6 inches thick at center of elliptical arch, and 16 feet between bearings. At 2 inches from the bottom of each side, forming the beam, were $1\frac{1}{2}$ x $1\frac{1}{2}$-inch twisted rods, one in each side.



- FIG 6 -

As it was evident this would require a very heavy weight to break it, preparations were made by laying four thicknesses of 2-inch plank across the top of slab, and projecting several feet on both sides. On this platform a strong frame was built, 15 feet long (from bearing to bearing) and 11 feet wide (just double the width of slab). The sides of this frame-work were not attached or secured to the plank platform so as to assist in any degree in supporting it. The frame-work was filled with clean sand, confined by planks, and the weight estimated by the cubic feet of sand at 100 pounds per cubic foot.

Load, Tons.	Deflection, Inches.	Remarks.
20	about $\frac{3}{8}$.	
50	" $1\frac{1}{2}$.	—Cracks on under side about 12 inches apart, in center third.

Load. Tons.	Deflection. Inches.	Remarks.
75	about 4.	—Cracks extending about 6 inches up.
90	" $6\frac{1}{2}$.	—Several cracks $\frac{1}{4}$ inch open at bottom and extending to within 2 inches of top when last seen by writer.

After standing in this condition for two or three days, more sand was added, when the concrete crushed near the center.

Before analyzing the remarkable results of this test, let us consider the proper method of estimating the strength of such composite beams.

1st—We must consider what is to be the effective depth of such a beam. It is evident the center of the tie-rods must be taken as the center of lower member; but the center of upper member is not so easily located, though it must lie near the top of the concrete.

It is evident that all the concrete above the neutral axis is subject to compressive stress—that stress being greatest at the top surface, and diminishing regularly to the center. It is also evident that as a beam deflects (and concrete, as it is well known, yields very little to compression) nearly all the strain must be met by a comparatively thin portion at the top.

It has appeared reasonable to the writer to assume the center of the top member as one-twelfth of the distance from the top surface to the tie-rods, and to consider that the concrete ($\frac{1}{12}$ of the depth) above and below this line must be sufficient to meet the compressive stress. Thus, if a beam is designed with a total depth of 15 inches, and the center of tie-rods placed 3 in. above the bottom of concrete, it would leave 12 inches as the entire depth from top surface to center of lower member. One-twelfth of this distance would be one inch, as the center of top member, thus leaving as effective depth of the beam 11 inches, and the thickness of top member two inches. Then if a 1 x 1-inch bar, with tensile strength of 25 tons, is used for the lower member and concrete that would crush with one ton to the inch, at the top, the beam should have a width of $12\frac{1}{2}$ inches to equalize the strength of the iron.

This is the rule the writer has used, and believes it errs on the side of safety.

Now, taking the sidewalk arch, as given above, and applying this rule and the usual formula for the strength of iron beams, we have as follows:

Length of beam between bearings..... 16 feet.
Depth from top to center of rods..... 13 inches.
Effective depth—about..... 12 inches.
Area of iron in tie-rods..... $4\frac{1}{2}$ inches.
Area of concrete in upper surface, 2 inches thick = 132 sq. in.

Then formula for breaking weight at center of iron beams—

$$\frac{\text{Depth} \times \text{area of iron in flange} \times 80}{\text{Length}} = \text{W in tons.}$$

$$\frac{12'' \times 4\frac{1}{2}'' \times 80}{192''} = \frac{360}{16} = 22\frac{1}{2} \text{ tons breaking weight at center,}$$

or 45 tons distributed load.

As this formula is based on the breaking strength of iron at 20 tons per square inch of section, and good grades of iron will require at least 25 tons to break by tensile stress, we may add 25 per cent. to this result, and consider that from 56 to 60 tons load on the arch and beams, should break the rods with tensile strain. Applying the formula for strains with 60 tons load we have this result: $\frac{60 \times 16}{8 \times 1} = 120$ tons tensile strain on $4\frac{1}{4}$-inches iron; also, 120 tons compressive strain on 132 square inches concrete, composed of one of cement to five of aggregates and five months old, which might reasonably be expected to carry one ton per inch.

It will be seen by the tables of weights and deflections of beams, that with about one-third of their breaking load the deflection was only about one-twelfth of the greatest deflections, and that the load required to produce a given deflection decreased regularly from the first. This may be readily accounted for by the fact that iron yields to extension quite regularly one-ten-thousandth of its length to each ton of load per inch until

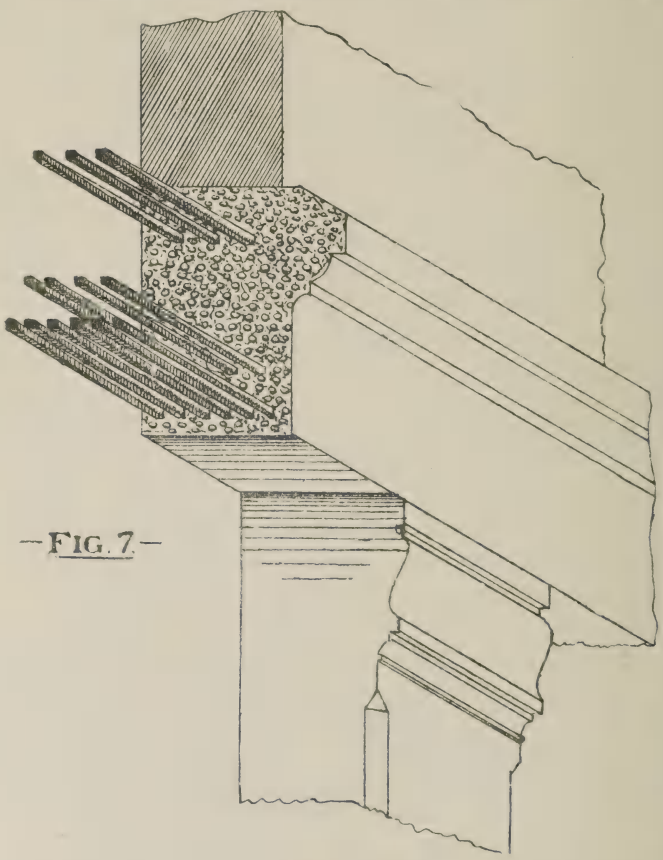
its limit of elasticity is reached, and then it yields more rapidly and in increasing ratio until some grades of iron will stretch one-tenth of their length before final rupture.

As concrete does not yield to compression more than about one one-thousandth part of its length before crushing, it is evident that as deflection increases in beams of this construction the neutral axis must move upward or nearer the top member, thus making less proportional strain on the lower and more on the upper member. This was very apparent in the last test noted, for when last seen by the writer the cracks due to extension had reached to within two inches of the top of the slab, showing conclusively that the neutral axis must be still higher.

Now, while this may account very satisfactorily for the iron rods not breaking as they then had a leverage of at least ten inches from the neutral axis, it does not account for the concrete not crushing, as the entire area of concrete then above the neutral axis could not be more than 100 inches and its greatest leverage about $1\frac{1}{2}$ inches, the stress would amount to the enormous load of 4.8 tons per inch for 60 tons load and 7.2 for 90 tons. It is incredible that concrete of such quality could resist such stress for a moment.

It appears to the writer that some of the compressive strain must have been transmitted to the four thicknesses of plank forming the bottom of platform, and some of the load, by friction at the sides. If this be so, it renders this experiment worthless so far as the ultimate strength is concerned, but could not affect the early stages of deflection. This arch and beams was designed to carry 400 pounds to a square foot, or total load of $16\frac{1}{2}$ tons with safety. When loaded to that extent its deflection was only about one-quarter inch. At this stage it could not have been relieved by the planks or the friction of sand on sides of curbing. The fact that such construction will deflect so much before breaking is a point in its favor, as it gives ample warning when it is overloaded. There have now been laid in this city about 50,000 superficial feet of sidewalk with spans from 10 feet to 22 feet, and no sign of failure or deflection under the heaviest loads that have been placed on them. The writer has applied this system in a variety of ways, some of

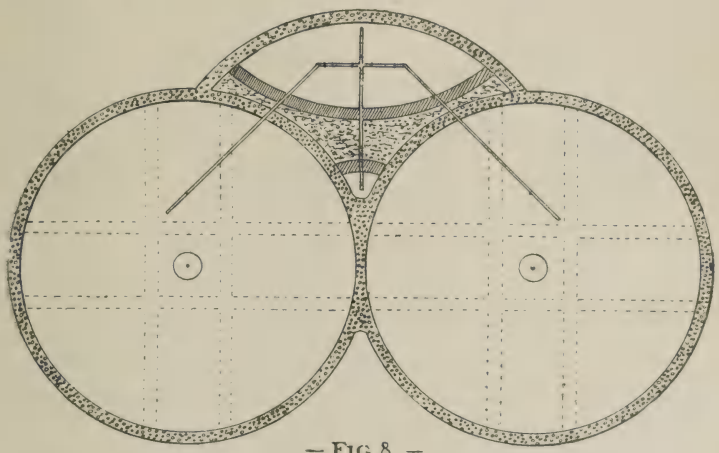
which will be noted. In the building on the northeast corner of Washington and Stockton streets the lintels over store fronts 15 feet clear span and carrying three stories of brick walls and wood floors, are of concrete 22 inches wide, 2 feet 10 inches high (with belt course moulded on), and 10 one-inch rods placed



—FIG. 7.—

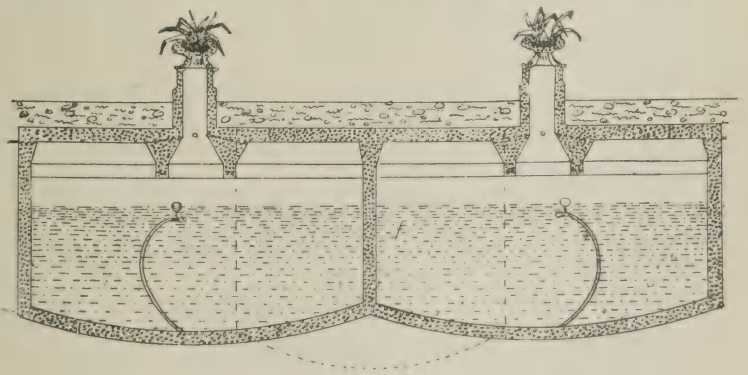
near the bottom. (Fig. 7.) These lintels extend along both fronts of the building, and over the supporting piers are placed three one-inch iron rods near the top, thus giving the effect of a continuous girder, although they were not needed for strength. The lavatory floors in this building are constructed as flat slabs,

6 inches thick, 10 feet span, with half-inch by half-inch rods every 6 inches, and placed $1\frac{1}{2}$ inches from bottom to center of rods. Other fire-proof floors have been constructed both with flat ceilings, beams and panels, and beams and arches.



— FIG 8 —

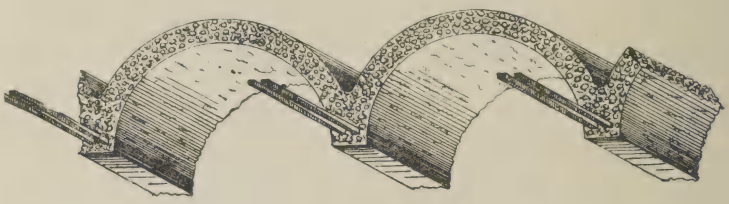
In preparing the underground cisterns at the residence of A. Hayward at San Mateo this method was employed with most



— FIG. 9 —

satisfactory results. The entire cisterns, filtering chambers, flat tops, curbs, and surmounting vases, were all executed in concrete, with two $1\frac{1}{4} \times 1\frac{1}{4}$ rods in each of the deep beams crossing each

other on each side of the center curb, as shown in Figs. 8 and 9. These cisterns are each 27 feet in diameter and 15 feet deep. The top is covered with two feet of earth, and drays loaded with iron pipe have been driven over them, although the top was designed to be in lawn and not intended for traffic.

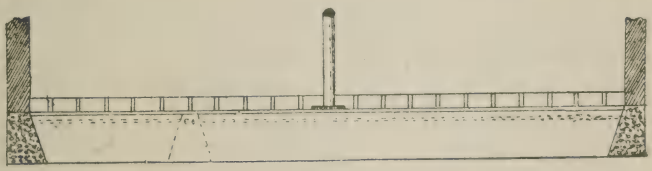


— FIG. 10. —

In 1885, Mr. Ransome erected the building for the Arctic Oil Company's works in this city, and made the roof over a fireproof warehouse in the manner shown in Fig. 10. Mr. Ransome describes it in this manner: "This roof is seventy-five feet long by twenty-five feet wide between the walls, which are its sole support. It consists of a number of winged beams, which, being made and jointed side by side, form the roof in a series of semicircular arches having a diameter of about three feet and a thickness of four inches, each beam containing two twisted iron bars one inch square and twenty-six feet long, placed about two inches from its bottom. Its calculated strength, verified by experiment, is eight times its constant load. Upon removing all temporary supports and scaffolding on the tenth day the roof did not show any deflection, although carefully measured to within an eighth of an inch."

In building a brick warehouse in Stockton in 1885 on newly made ground, the hard-pan being from twelve to fifteen feet from the surface, and desiring to save the expense of continuous foundations of such depth, piers of concrete were put in about fifteen feet apart and with footings on the hard-pan. At the surface of the ground a base course of concrete was formed with twisted rods of proper size extending from pier to pier. On this base course and girder were built the brick walls of the warehouse. In one or two places slight cracks appeared over the piers, which were evidently due to uneven settling.

In one other case, while constructing a brick building of two stories on very soft ground near our city front, the twisted rod and concrete combination was applied in the manner shown in Fig. 11. The footings of the side walls were not allowed to spread out on the adjoining property. Cross walls of concrete were built every fourteen feet, three feet wide on the bottom and three feet high, with two 1¼-inch twisted rods in each near the top, as is evident the tensile strain would be in that member. On the center of these cross walls rest the columns supporting the girder of second floor, while the first floor beams are parallel with the side walls and rest directly on the cross walls, thus distributing the weight of first floor and its load over the entire area. Some settling took place during the erection of this building, and several of the cross walls were cracked before the building was finished. No settlement has been observed since, and the brick walls have not cracked. The results in this case were as good as could be expected with a great depth of soft mud below. In such situations the entire area of the building should be covered with concrete and the rods placed as high as possible.



- FIG. 11 -

Twisted rods of iron or steel imbedded in concrete walls, floors and ceilings of bank vaults form a good burglar resisting substance, as well as being fire-proof. On one occasion, while building a concrete bank vault in an interior town, several tons of worn-out steel plow-shears were placed in the concrete in such positions as would be most likely to discourage burglars in attempting to cut through the wall.

Enough has been said to show the practical character of such combination of iron and concrete in building construction, while

many other applications will suggest themselves to the architect and engineer, as in the construction of domes, spires and tall chimneys; in bridges, dams, aqueducts and reservoirs it could often be used to great advantage in strength and economy. To suggest one great national undertaking where the writer believes better results could be obtained at less than half the cost of the present work: The Eddystone Lighthouses, both as built by Smeaton and the one recently completed. When one considers the great expense of the intricate dovetailing of the stones together, the trouble in handling and dowelling such masses and the comparatively shallow depth of the anchorage, and then consider that if built with concrete and iron it could be anchored with any number of twisted rods extending to any desired depth into the rock and grouted in with cement, holding at the lower end like the deep and spreading roots of a tree, while at the other end the rods could reach to the very summit, holding with an iron grip the capstone to the lowest depth; furthermore, for less than one-third the cost of stone, worked as was the stone in the Eddystone, Bellrock, and other lighthouses of that class, a concrete could be prepared of Portland cement, dense stone and iron shavings that would be from 30 to 50 per cent. heavier than granite and better to resist the action of water, while the trouble and expense of placing in permanent or temporary iron curbing would not be so great as handling the cut stone. It has been demonstrated on this coast that good concrete foundations for large engines are much more satisfactory than those built of brick or stone. Now, the writer would suggest that the bolts holding the engines to such beds should be of twisted square iron, thus taking a firm hold at all points through their length and not simply at the lower ends. For setting anchors, bolts or other fastenings in concrete, it is only necessary to twist square or flat bars of iron and imbed where wanted. Iron thus imbedded in Portland cement concrete, with sufficient thickness of cement around it, is perfectly protected from rust as well as fire, and cannot deteriorate with age. The writer believes the discovery to be of great value to the building world, and that its application will extend as its merits are appreciated and before many years will become general.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME V.—JULY, 1888.)

COMPARISON BETWEEN THE FRENCH AND CALIFORNIAN METHODS OF MANUFACTURING SALT FROM SEA-WATER.

BY F. GUTZKOW, MEM. TECH. SOC.

Read January 6, 1888.

Among the industries which have been fostered by the peculiarities of the climate of California, the manufacture of salt from sea water holds a prominent place. The States of the Pacific Coast, the Territories, so far as railroad charges will allow competition with the East, and several other countries situated on the Pacific Ocean, are supplied exclusively or principally from the salt made from the water of the bay of San Francisco. The operations practiced here in separating the salt may not appear to differ essentially from those practiced elsewhere. Still, there is some difference, due to climate and other causes, and it may prove, perhaps, not uninteresting to place the making of sea-salt in California and, for instance, France, side by side for the purpose of comparison. I will, therefore, present the translation of a very clear and concise report on the principal salt-works near Marseilles, published in 1883, by the distinguished chemist, Professor Lunge of Zurich, add thereto a description of our principal Californian works, following closely the order of Mr. Lunge's description of the French works, and, finally, point out the advantages of the two methods practiced.

THE FRENCH PROCESS.

The works of A. R. Pechiney & Co., says Professor Lunge, are situated on an island formed in the delta of the Rhone, and comprise 3,700 acres actually used for salt making. There being no notable tides in the Mediterranean, the sea water is lifted 27 inches high by a steam pump into the bed of a former lagoon of 600 acres area. Thence it flows into another lagoon of 3,000 acres area, which has a clayey soil and, naturally, a slight inclination to the center. The sea water enters with a strength of 3.6° Beaumé, circulates through several smaller ponds into which the large lagoon is divided, and arrives at the central reservoir with the specific gravity of 25° Beaumé, 1,000 gallons of the sea water having been concentrated into 102 gallons of brine. At 16° B. gypsum commences to separate. The process begins in May, lasts 150 days, and is much favored by the "mistral" (the dry northwestern wind of Southern France, which blows during several weeks).* The water circulating continuously, the supply has to be regulated by the steam pumps according to the progress of evaporation.

From the reservoir the concentrated brine of 25° B. is lifted by another steam pump to the crystallizing ponds. They cover 150 acres, and comprise four rows of eight ponds each. Each pond is 460 feet long and wide, twelve inches deep, and of a little less than five acres area. Parallel to the row of eight ponds runs the storing place of the salt, 5,000 feet long. It extends between two canals. One of them is the large shipping canal connecting with the Rhone river; the other one is filled with concentrated brine, and serves for carrying the salt from the 32 ponds to the storing place. Rectangular branches intersect in a suitable manner the ponds, so that each pond presents one of its four sides to the canal. The feeding ditch which brings the brine runs along the main canal and crosses the branch canals

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*The author states the evaporation on a favorable day to be "1 cubic meter per hectare," which should probably read: per "are," or 1,400 cubic feet per acre. The production of the works being 52,000 tons, I calculate the water evaporated on the 3,600 acres to be 83,000,000 cubic feet, or 23,000 per acre, or about 150 cubic feet per day and acre on an average.

by syphons.* The order of the plant is, consequently, as follows: Shipping canal, storage place, main brine canal, feeding ditch, four rows of ponds.

Through these rows of crystallizing ponds the brine flows in a slow but continuous stream, which is interrupted during night-time or unfavorable weather. It covers the bottom, or the salt already separated, 4 inches high, commences to separate salt at 25.6° B., and is allowed to run off at 27° B. At the close of the season the salt is found in a layer from $1\frac{1}{4}$ to $2\frac{1}{4}$ inches thick, and the yield is 350 tons (of 2,000 pounds A. d. p.) per acre, or 52,000 tons for the whole plant. The season of crystallization lasts 50 days; the harvest commences in August and lasts four or five weeks. Up to the beginning of harvesting all the labor required has been furnished by two men, who had charge of the regulation of gates. In harvesting, the mother-brine or "bittern," is removed as rapidly as possible, the salt carefully lifted off the bottom, thrown into heaps of six or eight tons each, allowed to drain a few days, wheeled toward the nearest point of the branch brine-canals and dumped into wooden boxes. These boxes rest on low barges. Each box holds two tons, each barge two boxes. The barges are hauled by mules to and along the main brine canal to a steam derrick, which lifts one box at a time and dumps the salt on the pile. The salt piles run in a straight uninterrupted line, in fact form only one enormous pile. It is 60 feet wide, $23\frac{1}{2}$ feet high, the sides slanting to within $4\frac{1}{2}$ feet from the bottom, when they become perpendicular. One running foot contains 26.8 tons of salt, assuming the weight of the loose salt to be one cubic meter=one thousand kilos; that is as heavy as water: 62.4 lbs. per cubic foot. Covering of the salt pile is dispensed with, the loss by rain being only 7 per

*Probably some local difficulty led to the rather poor contrivance of crossing one ditch by another by means of a "syphon." Fig. 1 represents the plan of the works as it may be understood from the description, the feeding ditch being placed in what I consider the correct position. Explanation is hardly required. From the author's description it does not appear whether the brine circulates through the row of four or of eight ponds. The drawing is made for four ponds, but may equally well apply for a row of more than four ponds. Fig. 2 shows a section through the feeding and discharging ditches.

cent. annually. The cost of the salt when thrown on the pile is ten cents per ton. All the salt made as described is supposed to be of one quality, No. 1. Its purity is promoted by allowing a certain alga (*Micrococcus Corvium*) to grow during winter, which covers the bottom of the crystallizing ponds with a uniform film one-sixteenth of an inch thick. For this purpose, sea-water is admitted to the ponds after harvesting is over to dissolve any remaining salt, and to form a weak brine of 8° B., in which the alga grows.

For the further concentration of the bittern, which measures 64 gallons from 1,000 sea-water, another system of 150 acres is provided, to wit:

38 acres for concentrating from 27° to 28.5° B., yielding salt No. 2.
69 acres for concentrating from 28.5° to 31° B., yielding salt No. 3.
26 acres for concentrating from 31° to 3 .5° B., yielding salt No. 4.
17 acres for concentrating from 32.5° to 35° B.,yields "sels mixtes," or mixed salts, consisting of chloride of sodium and sulphate of magnesium. No. 3 is used for pickling meat; No. 4 is thrown away. During the winter the bittern of 35° B. is stored in a cement-lined reservoir of 5 acres area, 13 feet deep, and separates "Epsom salt;" that is sulphate of magnesium. But also "Carnallite" will separate when the temperature sinks below a certain mark. Therefore the bittern is kept warm by a layer or current of sea water on the top, which will not mix with the heavy solution.

The bittern having become weaker by the separation of Epsom salt and measuring only 16 gallons from 1,000 sea-water is concentrated by artificial heat (Porion's oven) to 34° B.; measured while hot. A solution of chloride of magnesium, resulting in the progress of operations, as will be shown presently, is also concentrated by heat (ordinary iron pans) to 40° B. Both solutions are mixed in a certain proportion, when another batch of "sels mixtes" is obtained, which are added to the other lot. On cooling, carnallite separates from the mother-liquor; that is a double salt of the chlorides of potasium and magnesium. The liquid finally contains principally chloride of magnesium;

a portion is retained for the operation described above; the rest run to waste.

The conversion of the "sels mixtes" and the carnallite into marketable products takes place in the following manner: The "sels mixtes" are dissolved to a solution of 30° B., care being taken that the proportion of the constituents approaches the conditions of the equation $2NaCl + MgSO_4 = Na_2SO_4 + MgCl_2$. This solution is cooled by an ammonia ice machine to 42° F. Glauber salt, that is hydrated sulphate of sodium, separates in small crystals; is scraped and hoisted up by mechanical means; is freed from liquid in a centrifuge while still cold; is mixed with 45 per cent. of "sels mixtes," heated in an iron kettle to 176° F., and treated a second time in a centrifuge; this time, however, at a temperature not below 91° F. Thus it has been converted into the anhydrous sulphate of sodium, the commercial article used for glass making and soda manufacture. The mother-liquor returns from the centrifuge to form part of the 30° B. solution of "sels mixtes."

The carnallite separates readily by treatment with a suitable amount of fresh water into a solution of chloride of magnesium, which is allowed to run to waste, and undissolved chloride of potassium. It is treated in the centrifuge and contains, then, from 65 to 82 per cent. of ClK. Part of it is converted into chlorate of potassium at the company's chemical works; the principal portion, however, is sold for agricultural purposes.

Professor Lunge does not state the amount of chloride of potassium obtained per annum, and mentions only the daily production of thirteen tons sulphate of sodium, probably only during part of the year. I calculate that, in addition to the annual 52,000 tons of salt, there might be produced about 1,000 tons of chloride of potassium and 5,000 tons of sulphate of sodium.

The following analyses are given of the three grades of salt:

	No. 1.	No. 2.	No. 3.
$CaSO_4$	1.115	.621	.440
$MgSO_4$	.221	.506	.612
KCl	——	——	.122
$MgCl_2$	.100	.377	1.300
Insoluble	.050	.030	.050
H_2O	1.400	4.201	5.738
NaCl	97.100	94.212	91.217
	99.986	99.947	99.499

THE CALIFORNIAN PROCESS.

The works of the Union Pacific Salt Company are situated twenty miles southeast of San Francisco, at the point of a peninsula formed in the marshes of the eastern shore of the bay of San Francisco, between Mount Eden and Alvarado Creeks. Both creeks are easily navigable at high tide for sailing schooners of fifty and stern-wheelers of hundred tons' carrying capacity. The works comprise 1,300 acres utilized for salt making. The sea water is taken from Mount Eden Creek twice a year, that is, during the extraordinary high tides of the equinoxes, which rise about six feet in the creek, whilst the ordinary tidal movement is only from four to five feet. Large flood-gates allow a rapid filling of the first lake. This lake, as all others, is formed by throwing a levee up to the height which will secure against inroads of the bay; otherwise the marsh is left undisturbed, being horizontal and consisting of a clayey soil. After passing several other lakes, depositing gypsum, the brine of 24° B. is stored in a pond serving as a reservoir. The process is not continuous, but the lakes are emptied or filled when they obtain a certain concentration. The evaporation begins in April and lasts, rarely interrupted by a slight rain, until November; but even in winter the frequency of sunny days favor concentration, and already in May there is sufficiently strong brine on hand to commence the separation of salt in the crystallizing ponds.

The brine is lifted to them by wind power, which hardly ever fails during the whole year. They are of unequal size, the

largest being 300 feet long and wide (two acres), and are placed in one row, covering in all 24 acres. They are 12 inches deep; a few have wooden floors, but most only the black clay of the marsh as bottom. The floors give only indifferent satisfaction, as the liquid mud is very apt to soak through any cracks and spoil the salt during harvesting. The formation of an alga, like *Micrococcus Corvium*, referred to above, has not been observed in California. Parallel to the ponds run the discharging ditch, the feeding ditch, a railroad track, the salt piles, the wharf and Mount Eden creek, as represented on Fig. 3. The railroad serves for carrying the salt filled in sacks on the spot from the more distant piles to the wharf. The ponds are filled two, often three, some favorable year even four times, with concentrated brine, each time about ten inches high, and care is taken not to disturb the crystallization by addition of fresh brine. The bittern is run off not below 28° B., but reaches often 29° or 30° B. The salt is gathered every time the pond is emptied of bittern. The workmen are Chinese, who are paid one dollar per day. They work steadily and require little control, but soon fall into their own way of doing things, and cannot be driven. Since the import trade in Chinese has been restricted they have become quite independent, and strike on small provocation.

After the bittern has flown off, the salt is loosened by wooden spades and thrown into cones of half a ton each for draining. It is then wheeled to the salt pile fronting the pond and dumped four and five feet above the ground, the further throwing up being done by shovel. The salt piles are 32 feet wide, 16 feet high, sloping from top to bottom, and of varying lengths, generally 100 feet or less. They hold eight tons per running foot, and are left uncovered. The loss by rain is stated to be ten per cent.; the average crop 500 tons per acre of crystallizing ponds, the total production of the works 12,000 tons per annum, and the cost of one ton of salt, when thrown on the pile, 60 cents. The great bulk of the salt may be rated as No. 3. No. 2 is the salt made on the wooden floor and No. 1 that produced from three quarter acres of wooden vats 120x16x½ feet raised two feet from the ground, where particular care is employed for clean harvesting.

A portion of the bittern of about 29° B. is utilized for making carbonate of magnesium, for which there is a local demand as an absorbent of nitro-glycerine. The bittern is mixed with milk of lime, the separated hydrate of magnesium washed with water and converted into carbonate by furnace gas. An artesian well, 120 feet deep, and situated only a few feet from the wharf, flowing at the rate of 10,000 cubic feet per day, furnishes the water required.

A futher utilization of bittern has not been attempted. Sulphate of sodium or magnesium, or chloride of potassium, are things which sell in California only in drug stores. Perhaps the future development of agriculture, for instance, the making of beet sugar, may create a demand for cheap sources of potassium, as the Californian soil is notably deficient of that alkali. Some members of this Society have attempted to use the chloride of magnesium of the bittern for making cements and bleaching powder. If they did not succeed, their emptied pockets will show that they endeavored to follow science up.

The following analyses have been made by myself:

	Bay Water.	Sat'd Brine.	Bittern.	Bay Salt, Dried.
NaCl	2.3177	22.79	13.6713	99.434
KCl	.0458	——	——	
$CaSO_4$	.1232	.08	——	.436
$Na.SO_4$	——		——	.019
KSO_4	——		1.1972	——
$MgSO_4$	.1792	5.05	4.5621	——
$MgCl_2$	.2571		8.9435	.111
$MgBr_2$	.0024		.0898	——
H_2O and loss	97.0746	72.08	71.5361	——
	100.0000	100.00	100.0000	100.000

Professor Thomas Price, of this city, also states the percentage of dry bay salt to be 99.4 NaCl.

The works as described have been planned, erected and managed by Mr. A. B. Winegar, who never saw or read of European sea saltmaking, but followed exclusively his own practical good sense.

COMPARISON OF THE TWO PROCESSES.

In comparing the French and Californian works, I begin with the most important statement made, namely, that the ton of stored salt costs sixty cents here, and only ten cents in France. Whilst I have excellent authority for the Californian figure, I believe, I have reason to doubt Professor Lunge's correctness in this one point. The following analysis will, perhaps, support me. The labor and work required at the French establishment are:

1. By steam power.—To pump 3,000,000 tons of sea water and brine 2¼ feet high; to raise 52,000 tons salt 30 feet high by derrick.

2. By hand power.—To shovel 52,000 tons salt into cones; average lift say, 4 feet, distance, 6 feet; to shovel, wheel and dump into boxes 52,000 tons, distance say, 250 feet.

3. By mule power.—To drag 13,000 barges of 4 tons load each over say, 1,200 feet canal, and return empty.

I do not think that one of our members could take a contract for this work at $5,200, even at Marseilles prices of labor. With Californian labor, I would decline the job at twice that sum. Still, I have no hesitation in asserting that the French process is cheaper, consequently better, and ought to be adopted on this Coast.

The natural advantages of the Californian works are very great: nearness to the great market of San Francisco, accessibility on an excellent water-course, high tides which make pumping of sea water unnecessary, wind-power available during the whole year, the great length of the rainless season which allows to, at least, double the duration of the crystallizing period—all this ought to contribute much to balance the better condition of the French labor market. Some of the advantages enumerated explain the Californian yield of 500 tons per acre against 350 tons in France. By the continuous system of crystallization the great delays by interrupting the process several times and the over-concentration of the bittern could be avoided. For, although the separation of salt is facilitated by the increase of

chloride of magnesium in the brine, this is more than balanced by the slower evaporation from such concentrated solutions. Under such circumstances I think it quite probable that the yield per acre could be made twice that of France.

The advantages of a canal for transporting salt may appear less marked, as long as the Californian works, owing to their comparative smallness, can get along with one row of crystallizing ponds. But they would be valuable at other works, with less favored landing-place, which have to pay extra high freight to San Francisco, owing to the frequent strandings of the schooners. At one marsh, owned by Italians, near Mount Eden, the plan of moving salt by canal has been tried but found wanting, because the sides not being protected by boards, nor the bottom by the salt from the brine with which the canal ought to have been filled, it very soon filled with mud. At present, it serves only as a warning to our salt makers to avoid the repetition of the alleged failure. In the soft mud of our marsh land such canals will not stand without wooden protection, if they do elsewhere.

The hoisting of the salt by steam-derrick ought to be introduced at all large works by all means. The wheelbarrows ought to dump into boxes standing conveniently for the hoist. The saving in shovelling up and in valuable storage-room need not be discussed. The mere changing of staging for the wheelbarrow is, with Chinese workmen, a considerable item, and a trial for the good temper of the superintendent. The Chinese boss has rarely any authority over his men, and the white boss is generally misunderstood. Chinamen always chatter ceaselessly, when working, but when you hear them babble all at once, you may be sure a plank is to be moved. One thousand tons of salt stored in the Californian manner form a pile 125 feet long, covering 4,000 square feet, exposing 44 square feet surface to the rain per running foot, or $5\frac{1}{2}$ square feet per ton under 45° slant. The same weight stored as in France give a pile only 37 feet long, covering 2,200 square feet, offering 80 square feet surface per foot, or three square feet per ton under 33° slant. It will be said that the steeper the pile the quicker will the rain run off. This is not strictly correct, because the pile soon gets so

honeycombed that the water follows its own courses, and very little will run down the surface. On the other hand, the saltmakers, both here and in France, claim that the rain water purifies the salt from bittern. No doubt about that! But the rain acts only to the depth of a few feet, finding abundant channels to run down. The great core is left untouched. If it is desired to improve the salt by utilizing the rain, certainly some better device may be invented than throwing it up to a gigantic heap.

No practical person, saltmaker or not, will deny that it is much cheaper to remove the salt by one crop than to divide it into two or three, repeating the work of loosening salt, throwing it into cones, and laying a track for wheelbarrows two or three times. Nor will he deny that it is much cheaper to concentrate hoisting by derrick to a few weeks than extend it over a long, often interrupted, period. It is, also, more convenient and effective to superintend a large force of men working at one point for a short time, than to keep control over a small gang during the whole season, working to-day here and to-morrow half a mile away. I will here mention that I consider it quite feasible to store the whole crop of a pond during winter by filling the pond with bittern to the top and arranging a suitable overflow of the rain water. To practical saltmakers, who may claim to have tried that unsuccessfully, I answer, that I doubt if they filled the ponds high enough with bittern. Without saving some bittern during summer the plan will not work. If the Frenchmen are able to store during winter 6,000,000 cubic feet of bittern of 35° B. in an open reservoir of five acres' surface, I suppose we can store our salt the same way. I do not mean to advocate that as the proper way to store salt, but it may serve as a useful makeshift against the uncertainties of our labor supply.

The continuous system of concentrating the sea-water into brine will recommend itself to those saltmakers who are tired of tramping over miles of levees to watch the gates or to steal their way along the ditches at midnight to stop a windmill. The continuous system makes an intermediate pumping entirely unnecessary, and it is within the reach of possibility that a salt-

maker may sit in his easy-chair, sampling the brine to his left and with his right regulating by a twelve inch board the work of his cheap and faithful servant—the sun.

If my paper should contribute to place the Californian salt-maker of the future into this enviable position, I hope you feel yourselves rewarded for having listened to it.

Fig. 1.

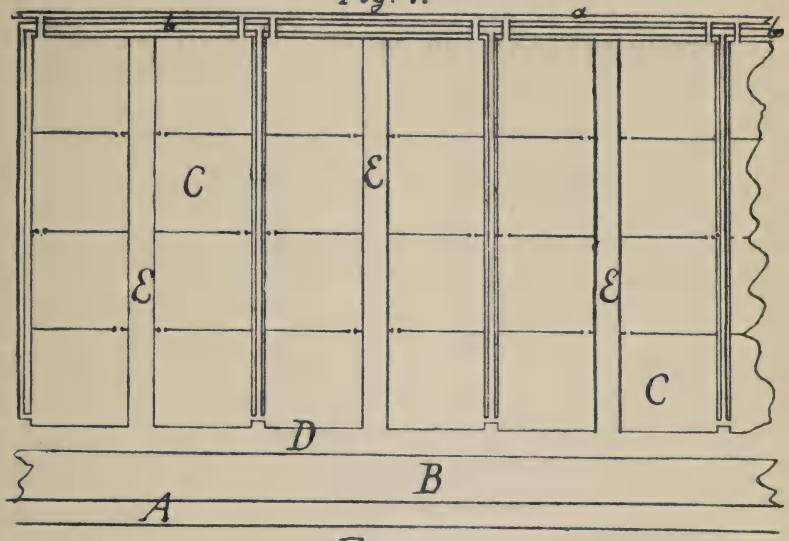
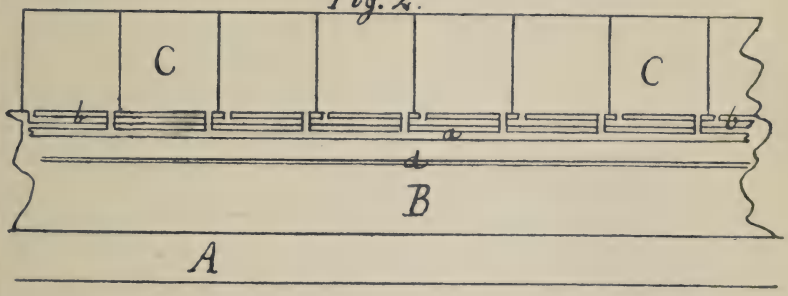


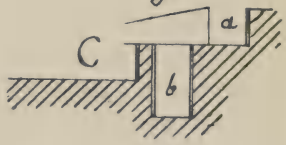
Fig. 2.



A—Shipping Canal.
B—Salt Piles.
C—Ponds.
D—Main Brine Canal.
E—Branch Brine Canal.
a—Feeding Ditch.
b—Discharging Ditch.
d—Railroad

[*Figs.* 1 *and* 2 *are not drawn to Scale.*]

Fig. 3.



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME V.—JULY, 1888.)

ON THE MAXIMUM VELOCITY ACQUIRED BY SMALL BODIES FALLING IN WATER AND GLYCERINE.

BY LUTHER WAGONER, MEM. TECH. SOC.

Read March 2, 1888.

The object of this paper is to show that the commonly accepted formula for the fall or suspension velocities of small bodies, such as ore grains, glass balls, etc., does not even approximately give correct results, and to suggest a new formula therefor.

To investigate this subject for ore grains smaller than one millimetre diameter, the following described apparatus was used.

A glass tube 22.7 mm. bore and 450 mm. long was drawn out at one end so that the dimensions were at the top of the tube 22.7 mm., at 230 mm. from top the same, at the bottom 10.1 mm. An U tube was joined to the bottom by rubber tubing, and thence from U to a reservoir; about one metre above the bottom of the U the reservoir was provided with an overflow weir so arranged as to maintain a constant head; a screw pinchcock on the tube from reservoir was used to control the flow.

The top of the glass tube has an encircling funnel-shaped col-

lar about 1½ mm. below the top of the tube, and a spout to conduct the water and ore into a measuring bottle.

A glass funnel 6.3 mm. diameter was placed in the axis of the large tube and reached to near its bottom. This funnel served to introduce the ore into the bottom of the apparatus.

The apparatus being filled with water, a small charge of ore introduced and the pinch-cock opened, the cross-section of the U tube being much less than that of the vertical tube the ore is carried up by the current, and some of the finer grains will go over even with a scarcely perceptible current. In the lower or tapered part of the tube the grains are rising and falling rapidly, while in the upper part the motion is a slower one. In a few seconds an equilibrium is established, the receiving bottle is placed under the spout and the time noted for its filling. It is next emptied, and the current being slightly increased by the pinch-cock, the bottle is again put under the spout to receive the first grains that come over, and the time for filling noted. The time, area of tube and volume of bottle being known, the velocity is computed from the mean of the two observations.

The sands brought over by the rising current are dried, weighed and counted, from which the mean weight of one grain is calculated. This method was used for grains between .30 mm. and .80 mm.; for the smaller diameters, comparison was made of the least diameter with that of the larger grains.

The quartz grains were, after being counted and weighed (.30 mm. to .80 mm.), placed under a microscope, and by means of the camera lucida, the outline of each grain was sketched upon paper, after which the micrometer scale was substituted for the slide and the scale was drawn upon the paper from which measurement of the least diameter was made. This was done to enable a comparison with the smaller diameters where weighing was not practicable. By the least diameter is meant the least diameter of an ore grain that with difficulty passes through a sieve. For the smaller ore grains a least diameter was drawn upon paper, as above described, and the average length measured. As a check the ore was sifted through sieves, and that part that came through last or slowly was weighed and counted, and the net aperture of sieve carefully measured.

The ore used was a clean quartzite from the New York Hill Quartz Mill, Grass Valley, Cal., stamped through No. 4 battery screen, specific gravity (in the water used) 2.645. For sieves the relation between the aperture of sieve and volume of grain was found, Volume = .46 diameter^3, and calling the least diameter *d*.

$$d = \sqrt[3]{\frac{\text{Volume}}{.46}}$$

For the measurement by camera lucida the co-efficient was found to be .449; multiplying by the specific gravity 2.645, the equation is

$$d = \sqrt[3]{\frac{\text{Weight}}{1.22}}$$

This equation was used to calculate the least diameter from the weight.

Pernolet experimented with grains from 4 to 30 mm. diameter by dropping the grains through a tube six metres high and noting the time. A reduction of his experiments gave me the following values of the above co-efficient: Quartz, 1.10; galena, 1.28; coal, 1.23. (See Annales des Mine, Vol. IV.) That is to say, square hole in sieve — $1.10\sqrt[3]{\text{Volume}}$ for quartz.

In the following table where the weights and least diameters are given, those derived by calculation are so marked.

Velocity of Water Current in mm. per second.	Average weight of Ore Grain in mgs.	Average least diameter of Ore Grain in mm.
	Cal.	Obs.
3.06	0.00013	0.055
	Cal.	Obs.
5.62	0.00055	0.0838
	Cal.	Obs.
15.77	0.000748	0.097
	Obs.	Cal.
45.00	0.042	0.325
	Obs.	Cal.
60.00	0.062	0.370
61.70	0.0785	0.401
84.00	0.114	0.518
84.00	0.130	0.474
92.20	0.334	0.649

Velocity of Water Current in mm. per second.	Average weight of Ore Grain in mgs. Cal.	Average least diameter of Ore Grain in mm. Obs.
92.30	0.318	0.639
100.40	0.358	0.665
104.50	0.372	0.673
106 00	0.396	0.687
120.40	0.445	0.714
133.00	0.494	0.740
146.00	0.557	0.770
161.00	0.637	0.805
174.20	0.660	0.815

The foregoing table is represented graphically in the annexed diagram by full round dots.

Pernolet's experiments show that the co-efficient a, in the formula $v = a\sqrt{\text{Density} - 1}\sqrt{d}$, where $v =$ velocity and $d =$ diameter of grain, varies with the form of the grain. A reduction of his work gives the following values for a:

Flat bodies falling flatwise..... $a = 41$
Average value..... $a = 70$
Rejecting highest and lowest ..... $a = 73$
Pyriform grains..... $a = 79$
Rounded grains. ..... $a = 80$
Spheres..... $a = 130$

From the foregoing it is seen that the form of the grain has great influence, and smooth regular curves can only be obtained by averaging a great many grains.

According to the usual formula in which

$$\text{Velocity} = a\sqrt{\text{Density} - 1}\sqrt{\text{Diameter}}$$

Pernolet's mean value of a is 70 for large grains of ore falling in still water. This value multiplied by $\sqrt{2.645 - 1} = 1.285$, becomes 90, while my experiments show that for $d = .65$ to $.80$ mm. $a = 141$ to satisfy the group of experiments between these limits. This may be due to some difference between a body falling in still water and that of a body in a rising current of water. As a check upon the above experiment with quartz

grains in water, glass balls falling in glycerine were also used. A vertical glass tube graduated in centimeters 50 centimeters long and 23 mm. bore, provided with a cock below to draw off the balls, was filled with commercial glycerine that had previously been heated to expel any air bubbles, and it was poured into the tube while hot and stood over night. The temperature of the room during the experiment varied from 17°.8 C. to 18°.5 C. The glass balls were made from glass rods. A thread was drawn from the rod and a button formed from the thread. After breaking off the thread the button was placed in a small cavity in charcoal and heated quite hot. This insured a nearly round ball. The diameters were taken with a Brown & Sharpe micrometer, each ball being measured in several directions and the mean was taken. The balls were allowed to drop some distance before taking the time, after which each 50 mm. was timed. If the intervals of time were regular the experiment stood; otherwise it was varied until fairly accordant results were found. There is probably more doubt about the balls being perfectly free from enclosed air bubbles than there is about the velocities or diameters.

TABLE SHOWING THE VELOCITIES OF GLASS BALLS FALLING IN GLYCERINE.

Velocity of the falling ball in mm. per second.	Diameter of the ball in mm.
10.08	2.63
7.91	2.27
6.43	1.96
6.42	1.94
4.36	1.48
3.71	1.34
3.42	1.22
2.20	1.01
1.33	0.79
0.897	0.71
0.611	0.534
0.277	0.340

The above results are shown upon the annexed diagram.

DISCUSSION OF THE DATA.

The simple inspection of the diagrams shows that the old formula $v = f\,d^{\frac{1}{2}}$ will not hold in this case. Therefore in seeking for a new equation it is necessary to take into account some of the factors that have been ignored in the earlier attempts at a solution of the problem. I conceive that the prominent factors omitted are as follows:

a. The adhesion of the molecules of liquid to each other.

b. The adhesion of the liquid to the immersed body.

c. Temperature.

A body that is wetted when withdrawn from the water will have an adhering coat of water, which the capillary attraction of the water below cannot wholly remove. Thus if a wire be dipped vertically into water and slowly withdrawn the surface of the water near the wire will be elevated above the general surface. Now if a skin of water of some thickness is supposed to adhere to the wire in the water, the weight of the adhering water, combined with the attraction of the mass below, will strip the skin to that depth or distance from the surface at which the adhesion of the water to wire equals the former force. Therefore it is a reasonable supposition that bodies immersed in water have a larger mass of adhering water than when the same ore is lifted out of the water. Coxe's Weisbach, page 1031, says that spherical bodies moving in water or air have a volume of water or air attached to them which is equal to .6 the volume of the sphere. This seems to have been determined from pendulum experiments and has been confirmed by Bessel, Sabine and Bailly.

The general formula now in use for the maximum velocity attained by a falling body in water is $v = a\sqrt{\text{Density} - 1}\sqrt{\text{Diameter}}$, which, omitting constants, may be written $v = f\sqrt{\text{Diameter}}$; but, as the platted data or free-hand curve shows that from 0 to .2 mm. the curve is reversed, some other factor must be introduced. Hence by the foregoing reasoning there should be a constant minimum skin, a thicker skin that is stripped away in

some manner inversely as the velocity and therefore inversely as the diameter, and finally these terms should vanish for the large diameters. These conditions are satisfied by writing

$$v = a \frac{d^{\frac{3}{2}}}{(d + b + \frac{c}{d})}$$

where $v =$ the maximum velocity, b the constant minimum skin, c a general constant and d the diameter of the body, $a =$ co-efficient.

For the glass balls in glycerine I have adopted

$$v = 8 \frac{d^{\frac{3}{2}}}{(d + \frac{1}{10} + \frac{2.5}{d})}$$

which satisfies the data between the limits in a very striking manner.

For the quartz grains in water the data does not admit of such nice treatment, and a modified formula is suggested.

$$v = 270 \frac{d^{\frac{3}{2}}}{(d + \frac{1}{1 + d})}$$

The curves shown upon the diagrams have been plotted from the above formulæ.

Concerning the co-efficient 270 there may be written $g\sqrt{2.645 - 1}$, from which $g = 210$ for quartz grains. Rittinger's value for spheres of quartz is $v = 207.2\sqrt{d}$ and Cazin's $v = 212.3\sqrt{d}$; but as angular bodies move slower than spheres, I think the value of 210 is too high for large bodies, but the difference may be due to the different methods of experimentation, viz., spheres falling in still water and ore grains suspended by a rising current of water.

The new formula shows that very feeble currents of water will carry away the finer grains of ore and readily explains why such a heavy body as mercury is so easily floured and swept away.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME V.—JANUARY—JULY, 1887.

MINUTES OF MEETINGS.

REGULAR MEETING.

January 6th, 1888.

In the absence of the President and Vice-President, Mr. E. J. Molera was selected as Chairman.

F. Gutzkow read a paper "On Comparison between the French and Californian Methods of Manufacturing Salt from Sea Water."

G. W. Percy read a paper on "Practical Applications of Iron and Concrete to Resist Transverse Strains."

The report of the Nominating Committee was received, as follows:

SAN FRANCISCO, Jan. 6th, 1888.

Officers and Members of the
Technical Society of the Pacific Coast:

GENTLEMEN—Your Nominating Committee begs leave to submit to you the following ticket, prepared for the purpose of electing the proper officers of the Society for the ensuing year:

For President—Mr. Marsden Manson.

For Vice-President—Mr. E. J. Molera.

For Secretary—Mr. Arthur F. Price.

For Treasurer—Mr. E. L. Ransome.

For Board of Directors—Messrs. W. W. Hanscom, H. C. Behr, W. G. Raymond, L. J. LeConte and E. C. Burr.

A letter from Mr. E. J. Molera is herewith submitted, in which he states that under certain circumstances he would cheerfully consent in serving the Society in any capacity.

Very respectfully,

F. Gutzkow,
G. W. Percy, } Committee.
A. d'Erlach,

Otto von Geldern, Sec. of Com.

ANNUAL MEETING.

January 27th, 1888.

In the absence of President and Vice-President, Mr. E. J. Molera was elected Chairman.

Messrs. Van Geldern and Keith, who were chosen to count the ballots, reported thirty-five votes cast for the following officers for 1888:

President, Marsden Manson, 34 votes; Vice-President, E. J. Molera, 34 votes; Secretary, Arthur F. Price, 35 votes; Treasurer, E. L. Ransome, 35 votes. Directors—H. C. Behr, 35 votes; W. G. Raymond, 35 votes; L. J. LeConte, 35 votes; E. C. Burr, 35 votes; L. Wagoner, 8 votes; F. Gutzkow, 3 votes.

Treasurer Manson made a report of the condition of the finances, and the meeting adjourned.

REGULAR MEETING.

February 3d, 1888.

Owing to the proximity of the Annual Meeting, the Society did not meet in February.

REGULAR MEETING.

March 2d, 1888.

President Manson in the chair.

A paper prepared by Mr. Luther Wagoner, "On the Maximum Velocity Acquired by Small Bodies Falling in Water and Glycerine," was, in the absence of the author, read by the Secretary.

An informal discussion on the subject of oils was participated in by Messrs. Manson and Percy.

REGULAR MEETING.

April 6th, 1888.

President Manson in the chair.

Mr. E. C. Burr gave an interesting description of a stoppage which had occurred in the drain-pipes at his residence in this city. Various remedial agencies, and amongst them a pump and the inevitable plumber, were tried, but no relief was experienced until a strong solution of caustic potash was used, after which the water ran freely. Mr. Burr obtained from the pipes some thirty-one feet of a tough, jelly-like fungoid growth, and this it was that had caused the trouble. This growth is renewed after a time, necessitating occasional applications of caustic potash. If the fungoid material is placed in a bottle it will grow indefinitely. Mr. Burr believes the growth to be occasioned by the decomposition of fatty acids, and its life to be sustained by the current of air which flows up through the pipes.

Mr. A. F. Price presented a few practical experiments showing simple tests for the detection of adulterations in oils, based on the characteristic cohesion figures formed by various oils when dropped carefully on the surface of water contained in a large dish. Pure and adulterated oils were shown, and the identity of each was readily recognized.

Mr. Marsden Manson exhibited to the Society a series of charts issued by the United States Signal Office at Washington, showing the course of the late storm which traversed two-thirds of the globe.

This meeting falling within a few days of the fourth anniversary of the formation of the Society, the members adjourned at its conclusion to a neighboring restaurant. where a few hours were pleasantly employed in the discussion of matters not technical.

REGULAR MEETING.

May 4th, 1888.

In the absence of a quorum, the meeting was not called to order.

REGULAR MEETING.

June 1st, 1888.

President Manson in the chair.

Mr. John D. Isaacs was elected a member of the Society.

Mr. N. S. Keith read a paper on the "Desilverization of Lead by Electrolysis," after which Mr. A. d'Erlach gave a lucid description of the new cruiser "Charleston," now being constructed in this city.

By a vote of the Society, the Directors were authorized to arrange for a series of popular lectures on scientific subjects during the present year.

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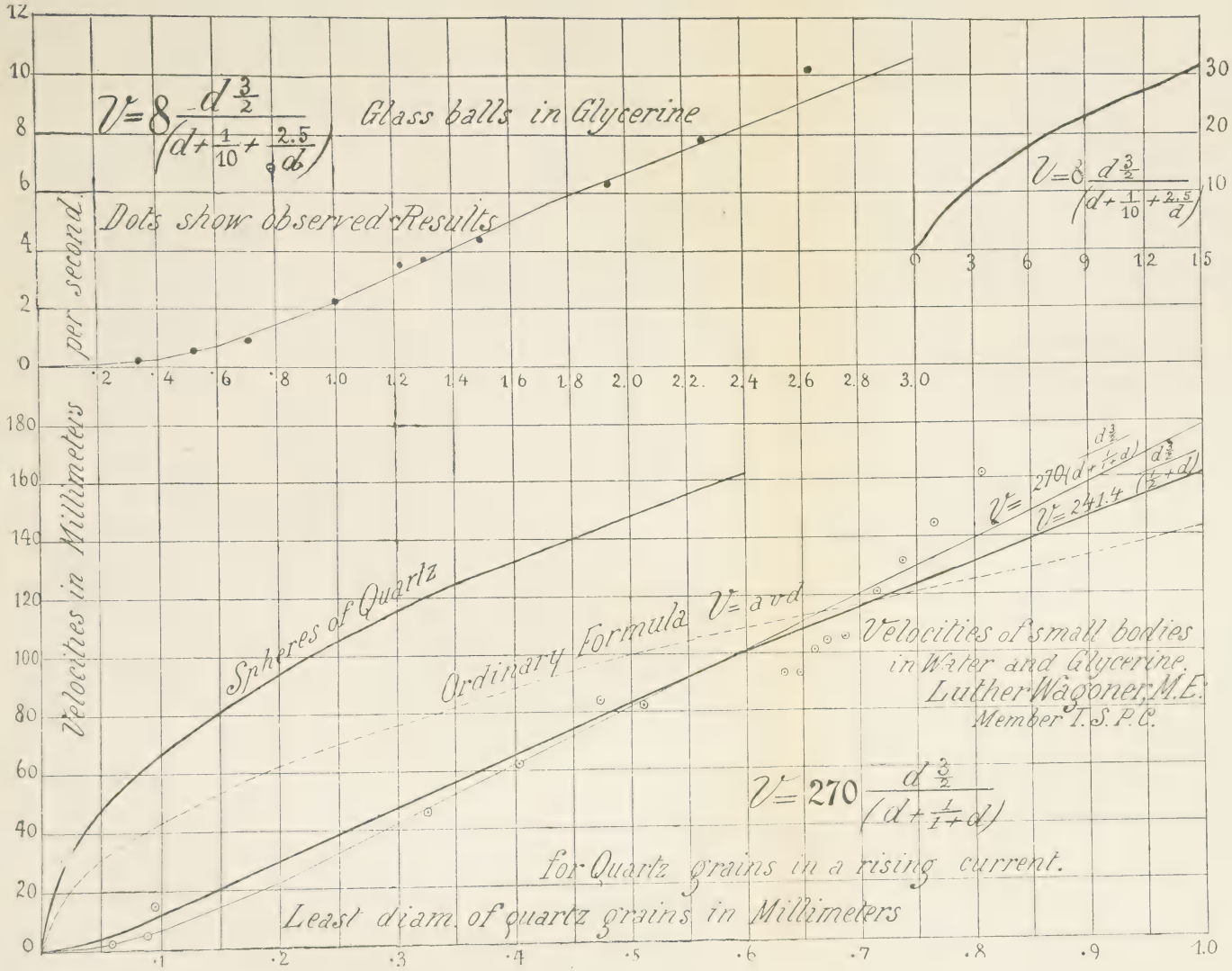
$V = 8 \frac{d^{\frac{3}{2}}}{\left(d + \frac{1}{10} + \frac{2.5}{d}\right)}$
Glass balls in Glycerine
Dots show observed Results
$V = 8 \frac{d^{\frac{3}{2}}}{\left(d + \frac{1}{10} + \frac{2.5}{d}\right)}$
Velocities in Millimeters per second.
Spheres of Quartz
Ordinary Formula $V = a\sqrt{d}$
$V = 270 \frac{d^{\frac{3}{2}}}{\left(d + \frac{1}{1} + d\right)}$
$V = 241.4 \frac{d^{\frac{3}{2}}}{\left(\frac{1}{2} + d\right)}$
Velocities of small bodies in Water and Glycerine.
Luther Wagoner, M.E.
Member T.S.P.C.
$V = 270 \frac{d^{\frac{3}{2}}}{\left(d + \frac{1}{1} + d\right)}$
for Quartz grains in a rising current.
Least diam. of quartz grains in Millimeters

TECHNICAL SOCIETY OF THE PACIFIC COAST.

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(VOLUME V.—AUGUST, 1888.)

THE CALIFORNIA GEYSERS.

BY THOMAS PRICE, M. D., MEM. TECH. SOC

Read July 6th, 1888.

The object of this paper is to present a series of analyses which I have made of samples of water obtained from several springs at the California Geysers.

The Geysers are located in Sonoma county, sixteen miles east of Cloverdale, and twenty-five miles northwest of Calistoga, from both of which points they are approached over roads abounding in romantic mountain scenery.

The volcanic phenomena are exhibited at various points, covering an area of something like four hundred acres, although the seat of greatest activity is confined to a narrow cañon comprising about sixty acres. Scientific authorities are unanimous in declaring that the phenomena observed here are not those of true geysers, but rather of what are known as fumaroles.

Most of the springs are located on the north side of Pluton river, into which the greatest part of them empty their waters.

These springs have a perennial flow, and the volume of water issuing from them all, at temperatures varying from 100° to 212° Fahrenheit, is not less than 100,000 gallons per day.

The formation of the surrounding country is serpentine and sandstone, on which the heated gases, free hydrochloric and sulphuric acids, and carbonic acid gas, issuing from the springs, have had a strong disintegrating action.

The ground near the springs is hot under foot, and steam issues from innumerable vents and cracks in large quantities.

At many points where the fumaroles have died out, deposits of sulphur and cinnabar are found in considerable quantity.

In the immediate neighborhood, quicksilver mines have been opened, and a few years ago were quite extensively worked. Considerable quantities of sulphur have also been extracted for shipment to San Francisco.

For many years this section had a great reputation among the Indians on account of the remedial qualities of the water, and a different therapeutic value was attached to each spring, one in particular being known as the "Eye-water spring."

The alum spring, shown in the table of analyses, presents several points of resemblance to the Rockbridge alum springs of Virginia, which are extensively used for bathing and drinking purposes, and have been highly endorsed by leading medical authorities. The name "alum spring," however, as popularly applied to springs of this character, is a misnomer, as they are really aluminous sulphated chalybeates.

The various springs showing the presence of free sulphuric acid, are very similar to the well-known acidulous springs in the State of New York, which have long enjoyed a great reputation for their curative powers.

The several sulphur waters are similar to others found on this coast, and elsewhere in the United States and Europe.

I am satisfied that the value of these waters for bathing purposes will meet with due recognition at no distant day. The great volume of water issuing from the springs, at different temperatures, will enable the temperature of the bath to be easily controlled; whilst the large quantities of nearly dry steam which are given off, suggest the facility with which a series of Russian and Turkish baths might be arranged.

There are numerous mud baths, with temperature varying from 70° to 110° Fahrenheit, the curative powers of which, in

rheumatic and cutaneous diseases, deserve greater recognition than has been accorded to them in the past.

Uninviting as the mud bath looks, a pleasant sensation supervenes when the first disagreeable feeling caused by contact with the slimy-looking ooze has passed away.

These baths bring out eruptions more readily than do mineral waters, as well as increasing the activity of all the functions of the skin.

A more detailed study of the therapeutic properties of the various springs, cannot but lead to valuable and interesting results.

Analyses of Waters from Several Springs at the California Geysers.

SAMPLES TAKEN AND ANALYZED BY THOMAS PRICE, M. D.

Contents per U. S. Gallon Expressed in Grains.	Lemonade Spring. Temp. 103° Fahr.	Witch's Cauldron. Temp. 212° Fahr.	Acid Spring. Temp. 140° Fahr.	Alum Spring. Temp. 136° Fahr.	From Geyser Creek (below Alum Spring). Temp. 96° Fahr.	Spring on side of Hill (near Pluton River). Temp. 138° Fahr.	Iron Spring (South of Hotel). Temp. 70° Fahr.	Indian Spring. Tem. Water, 108° F. Temp. Mud, 110° F.	Indian Spring (near Cloverdale Sulphur bank). Supposed real Indian Mud Spring. Temp. 100° Fahr.	Spring little above Indian Spring. Tastes very acid. Temp. 105° Fahr.	Hotel Sulphur Water in bed of Pluton River, little above bath house. Temp. 140° Fhr.	From Spout of Devil's Teakettle. Temp. 212° Fahr.
Bisulphate of Potassa	7.53	0.42	1.14	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sulphate " Potassa	.....	.....	.....	.....	.....	.....	.....	0.21	.....	.....	.....	.....
Bisulphate " Soda	53.91	39.83	9.62	5 14	.....	.....	.....	.....	17.12	.....	.....	98.16
Sulphate " Soda	.....	.....	.....	.....	3.15	3.23	.....	3.29	.....	.....	2.36	.....
Carbonate " Soda	.....	.....	.....	.....	.....	.....	.....	1.40	.....	.....	.....	.....
Sulphate " Lime	.....	6.98	4.44	3.81	5.34	1.10	3.32	.....	6.42	8 72	0.65	4.36
Carbonate " Lime	.....	.....	.....	.....	.....	.....	.....	7.35	.....	.....	.....	.....
Silicate " Lime	.....	.....	.....	.....	.....	10.18	.....	.....	.....	.....	.....	.....
Borate " Lime	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6.62	.....
Sulphate " Magnesia	40.73	9 62	91.29	34.49	16.66	.....	2.52	.....	59.33	41.12	.....	39.09
Carbonate " Magnesia	.....	.....	.....	.....	.....	.....	.....	15.47	.....	.....	.....	.....
Silicate " Magnesia	.....	.....	.....	.....	.....	15.46	.....	.....	.....	.....	.....	.....
Borate " Magnesia	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.31	.....
Sulphate " Iron	12.25	.....	16.63	7.34	0.08	0.11	.....	.....	.....	28.81	0.16	.....
Carbonate " Iron	.....	.....	.....	.....	.....	.....	0.12	0.07	.....	.....	.....	.....
Sulphate " Alumina	32.02	2.04	20.62	63.82	.....	0.20	.....	.....	22.78	118.78	2.39	31.16
Alumina	.....	0.27	.....	.....	0 89	.....	0.17	0.18	.....	.....	.....	.....
Free Sulphuric Acid	31.82	.....	154.37	6.45	.....	.....	.....	.....	32.30	5.75	.....	110.64
Hydrochloric Acid	1.19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Silicic Acid	16.50	4.37	21.11	17.26	3.50	17.25	0.99	5.42	12.25	18.08	8.63	12.83
Sulphurated Hydrogen	Saturated	Saturated	Saturated	Saturated	Saturated	Saturated	.....	Saturated	Saturated	Saturated	Saturated	Saturated
Boracic Acid	.....	.....	S. traces	.....	.....	.....	.....	.....	.....	.....	Str. traces	.....
	175.95	63.53	319.22	138.11	29.62	47.53	7.12	33.39	150.20	221.26	38.12	296.24

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE MANUFACTURE OF MAGNESIA FROM SEA-WATER IN CALIFORNIA.

BY F. GUIZKOW, MEM. TECH. SOC.

Read August 3d, 1888.

In my paper on "Salt-making in California," published in No. 1, Vol. V., of the Transactions of this Society, I wrote: "A portion of the bittern of about 29° B., is utilized for making carbonate of magnesium. The bittern is mixed with milk of lime, the separated hydrate of magnesium washed with water and converted into carbonate by furnace gas."

When I, jointly with the Union Pacific Salt Company of this city, erected the magnesia works referred to about eight years ago, I could obtain from the technical literature little more information than the above paragraph yields. I knew from the patent of Pattinson, who invented the process many years ago, that the carbonic acid gas was to be forced into closed iron cylinders, also that in England the crude material was dolomite, and I could assume that the cheap sources of pure carbonic acid, that is chalk and otherwise valueless diluted muriatic acid, would offer to the English manufacturer a better material than furnace gas. Whilst gathering experience myself I readily understood from the numerous unexpected difficulties encountered, why the published descriptions were so meagre. Apparatus and manipulations being, therefore, of independent Californian growth, a description will perhaps not be without interest.

In planning the works it was out of question to employ such costly apparatus as air-compressors and closed iron cylinders. The small and uncertain market of this Coast for magnesia allowed only cheap plant and cheap working. If the waste gas from the steam-boiler which furnished the power could not be utilized, and a Root or Baker blower proved insufficient, the process would be financially a failure. The price of magnesia was inviting enough. The powder companies paid 18 cents a pound. Our competition soon lowered the price to 10 cents. Even at that figure a large profit was required, in consideration of the small sale. The article previously imported from England was very superior and difficult to equal.

The diagram represents a section through the plant showing the apparatus in one continuous line. The apparatus consists, beside steam-boiler, blower, engine, steam pumps and grinding mill (the last three not shown in the figure), of round tanks made of redwood, square boxes for filtering and drying. The sheds are in the primitive Californian style too familiar and plain to need or invite description. The marshy soil necessitated an independent spacious plank foundation for every large tank or heavy piece of machinery. The connection between the several tanks had to be made by rubber hose interpolations. When one of the 6,000 gallon tanks discharged into another one of equal size, the empty tank rose some inches while the one just filled sank as much. Things have become gradually more settled. The actual arrangement is, of course, less regular than represented in the diagram because some parts had to be placed near the steam-boiler.

PREPARATION OF THE MAGNESIUM HYDRATE.

The bittern is lifted by a steam pump to tank (1). This redwood tank, 12 feet diameter 8 feet high of 3-inch material, holds 6,000 gallons and costs $100 in San Francisco. The peculiarity of redwood which it shares with other wood to shrink in salt brine makes it necessary to tighten the hoops periodically for several months before the tank is quite tight. No further difficulty is then, however, found in that respect. The bittern as taken from the ditch is of a reddish color, slimy to the touch,

and holds in suspension much earthy and organic matter, among which are innumerable small live animals.

My paper on "Salt-making, etc.," gives a chemical analysis. It will be sufficient to state that it contains, or rather yields with lime, from 6 to 7 pounds magnesia (MgO) per cubic foot. Filtering is out of question. Of the several devices to clear the bittern the old expedient of alum was found to be the best. The impurities rise with the separated alumina to the surface. The foam shrinks into a crust by heating the bittern. This crust is, after draining, thick enough to be lifted off with a shovel. Nothing sinks to the bottom and the bittern is water clear and without color. About 200 pounds of alum are required for the 6,000 gallons in (1), the amount varying somewhat according to the month of the season. A previous test with a standard solution of alum easily shows the weight of alum required. The foam is 12 inches thick and shrinks into 3 inches by heating to 180° F., and to 1 to 2 inches after draining. The device sketched in the diagram worked very well. It consists of a false bottom of boards, nailed on two cross boards into a disk which fits loosely to the top of the tapering tank and leaves small interstices between the boards. A strong plank is fastened across the top of the tank and braced by an upright scantling set into the bottom of the tank. Two other uprights are fastened to the false bottom and slide in square holes cut into the plank. Thus a true and easy up and down of the false bottom is secured. Holes in the moving uprights and pins through them allow to keep the contrivance to the bottom when the tank is empty, or to suspend it from the plank when the tank is full. When the tank is empty and the false bottom secured to the bottom of the tank in the manner described, the alum is thrown in where the leaden steam pipe opens, the tank filled with bittern, steam turned on and shut off after the desired temperature has been reached, the pins loosened (which causes the false bottom to rise to the top) and placed in other holes in the uprights above the plank. Then, an inch or two of the clarified bittern is allowed to run into tank (2). Thus the scum may drain and can be shovelled off. An inch or two of water added sets the false bottom afloat again, and it will sink again to the bottom when tank (1) becomes

empty. In the progress of experience it was found that this manner of clearing the bittern was only required when magnesia of a superior quality for medical purposes was to be made. For the bulk of magnesia sold as an absorbent for nitro-glycerine a much plainer and more economical way of applying the alum was introduced to be described hereafter.

Tank (2) serves only as a reservoir for the clarified bittern. Some particles of scum may be ladled off here or made to sink to the bottom, the outlet of the pipe connecting with tank (3), being 12 inches above the bottom of (2). The bittern having become weaker by steam and water and being of varying strength in magnesia, is to be tested for its percentage of magnesia so that the workman may know how many inches of the bittern are required for each charge of lime, the latter being a constant weight. I dilute 10 c. c. of the bittern with about 40 c. c. water, add one cubic centimeter of a standard solution of caustic soda, suck with a pipette a sample of the settled liquid and test in a test-tube with another c. c. of the soda. If still a precipitation of magnesium hydrate takes place, the test-tube is emptied into the original solution, and so on. As only approximate determination is needed, and the volume of standard solution which can be given with safety is known, this test is sufficiently close and speedy. Tank (2) being of the same dimensions as (1) holds enough bittern for a week or longer.

The lime is slaked in (4), which is 6 feet diameter and 3 feet high, and placed with regard to tank (3) so that no unnecessary lifting of the lime barrels is required. The lime comes from Santa Cruz in barrels of about 200 pounds net and costs $1.25 a barrel net. It is of superior quality and gives a more bulky milk of lime than the lime coming over Sacramento. Ten grains of it dissolve with muriatic acid to a clear solution with a small residue of heavy sand. The solution gave with ammonia .040 grains of mixed alumina and ferric oxide, and contained only traces of sulphuric acid and magnesia. It would be difficult to find a purer lime anywhere. Of course only the best quality, consisting of picked lumps and used for white washing can be employed. Ten parts of hot water are employed for one part of lime. The tank is filled two feet high with water of 180° F. and

1½ barrels of lime thrown in, in two or three portions. A suitable cover protects the workman against splashing. The water gets at once into violent boiling. The milk of lime is stirred as soon as boiling ceases, and allowed to run into tank (3) which has the same dimensions as (1) and (2), to within 2 inches from the bottom of (4). More water is run into (4) to dilute the remaining slaked lime and to fill (3) up to a certain constant height. Now the proper amount of bittern is added, the tank (3) filled to the top with water and allowed to settle. A reasonable speed and pipes of liberal dimensions are required to save time and prevent separation of gypsum. A wooden stirrer turning round a pivot in the center of the tank (3) is used and turned by hand, as a good mixing in a tank of this size can only be reached by frequent reversals of the stirrer. Several large faucets serve to run the liquid off as soon as it is settled. The lowermost faucet is 21 inches over the bottom of (3). The washing with water is repeated three more times. To recapitulate: 300 pounds of lime are slaked with 50 cubic feet water, the milk of lime diluted with 50 cubic feet more water; 40 to 50 cubic feet bittern added containing about 250 pounds of magnesia, the whole settling into 200 cubic feet of magnesia pulp and 600 cubic feet of solution, which, being replaced three times with pure water, brings the consumption of water to about 2,500 cubic feet, or 775 parts for one of magnesia (MgO). The preparation of the milk of lime and of the filling of the first tank full takes one hour—settling, emptying and recharging three hours. The volume which the magnesia pulp assumes depends on the quality of the lime and of the dilution. A better pulp—more light and uniform—is obtained by running the bittern into the milk of lime, than vice versa. The large amount of water required might be lessened by using the last two washings for the first of another operation or by washing oftener with less water at a time. The pulp contains per cubic foot about one pound of MgO as magnesium hydrate, some lime and gypsum, both, owing to their solubility in large quantities of water, less than one might suppose all suspended, and most of the organic matter in bittern or water, and carbonate of lime (about 6 per cent. of the MgO). The carbonate of lime is formed from the

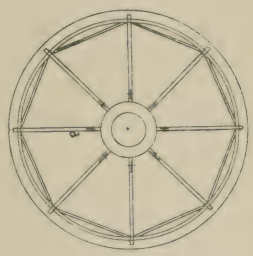
bicarbonates of soda, lime and magnesia in the water. At our works the water is obtained from an artesian well only a few feet distant, is quite clear but contains considerable of those bicarbonates. The washed pulp is finally run off into the reservoir (5). There being two tanks (3) in the plant, two of the operations just described are made every day, three barrels lime used and 400 cubic feet of pulp with 400 pounds MgO collected in (5) every twenty-four hours.

CONVERSION OF THE MAGNESIUM HYDRATE INTO CARBONATE.

The chemistry of this operation presents no novelty. Carbonic acid gas is passed through the pulp of magnesium hydrate, the solution of magnesium carbonate thus obtained is settled from the undissolved residue and is heated to the boiling point, when the basic carbonate is separated, which, after drying, yields "magnesia alba," the commercial article which contains 43 per cent. magnesia, 36 carbonic acid and 21 per cent. water, only slightly varying in composition.

A different plan was, however, followed when the works were opened. The pulp was heated to 120° F. during the carbonization, the temperature finally increased to 180° F., and the pulp filtered and dried; the solution itself retaining only traces of magnesia was run to waste. Thus the 6 per cent. of carbonate of lime previously referred to were left in the product as they were supposed not to interfere with the use as an absorbent. The organic matter had, of course, to be removed by the alumnization of the bittern as described. This process was much cheaper than the one finally adopted; the carbonization was rapid, the neutral carbonate ($MgCO_3 3 H_2O$) and the basic compound formed at once, the former was converted into the latter by heating to 180° F., and the carbonic acid evolved therefrom acted on particles of the magnesium hydrate still remaining. In the laboratory as well as on the large scale, the magnesia thus obtained was most voluminous. One gram of the sifted magnesia filled 18 c. c., whilst English magnesia filled only 9–10 c. c. There was only slight difference in chemical composition, to-wit: a deficiency of about one per cent. in carbonic acid and corresponding surplus in magnesia. But this was sufficient to de-

stroy the value as a good absorbent. The deterioration was less noticed when the filtered pulp was at once and rapidly dried, which could not be imitated on the large scale. After a series of worrying experiments when all combinations of time, temperature, division of pulp were tried, not to mention changes of apparatus, this process was abandoned for that which I shall describe now.



The pulp of magnesium hydrate is lifted by a pump from the reservoir (5) to the tank (7), which serves as charging tank for the carbonizer (8), and is mixed during pumping by a rotary stirrer in (5), driven by machinery. The apparatus (8) is the most important of the whole plant. It consists of a round tank 6 feet high, 7 feet diameter at the top and 6 feet 2 inches at the bottom. A copper pipe of 6 inches diameter, which opens into a conus of 12 inches diameter at the base, leads the blast to within two inches from the bottom. Here the blast spreads underneath a false bottom of sheet-copper perforated with holes of one-sixteenth-inch diameter, one hole per square inch. This false bottom has 6 feet diameter, and rests partly on the flange of the blast-pipe, partly on wooden strips 2 inches high, which spread radially over the tank and partly on similar strips nailed along the circumference of the tank. The copper sheet is divided into eight segments, which are kept in position against the blast, which tends to lift them, by the wooden braces (*a*). These braces are placed radially to the tank so as to cover the joint between two segments which rest here on one of the wooden strips mentioned previously. A recess chiseled into the staves of the tank holds one end of the brace. The other end is held by a wooden wedge which is driven through the eye of an eye-

bolt screwed into the tank bottom. A hole through the brace allows the eye of the bolt to pass so that the brace can be lifted off the copper sheet and pulled out of the recess in the tank staves when the wedge has been knocked away. The tank is filled with the magnesia pulp only two feet high, but is made six feet high and tapering in order to retain the copious foam which is gradually generated in the process of carbonization. The solution obtained is not bicarbonate of magnesia, as might be supposed, but sesquicarbonate, with three equivalents of carbonic acid for two of magnesia. Neither is it possible to obtain in the laboratory under similar circumstances (that is, by sucking the cooled gas from a Bunsen burner with admixture of air through the pulp by means of a Bunsen vacuum pump) a solution of bicarbonate, be the operation ever so long continued. Neutral carbonate of magnesia will be precipitated in comparatively large and hard crystals, which are very slow in redissolving, and adhere tenaciously to glass, wood or metal. The tank (8) becomes gradually lined with a crust, one or more inches thick at the end of the season of six months, and the holes in the false bottom become clotted, necessitating a cleaning of the copper sheet at least once a week. Therefore, the construction in segments and the described contrivance for securing them, which I can recommend for similar operations as substantial, cheap and effectual. The copper segments are cleaned by placing them into a tank filled with diluted sulphuric acid. Stop-cocks, faucets, couplings and other brass implements are cleaned in the same way. Iron pipes are employed in lengths not over four feet, are unscrewed and placed into the boiler-fire. The steam generated from the hydrated salt causes the crust very soon to shoot out as a powder with a noise like a pistol shot.

The blast is furnished by a Baker blower, No. 2, from the products of combustion of the boiler-fire. The blower, which delivers theoretically seven cubic feet per revolution, makes 120 to 150 revolutions per minute, and is driven by a horizonal engine working with 8 to 10 horse-power. The boiler, which generates all the steam required in the establishment, is of the usual locomotive pattern, 3 feet 4 inches diameter and 16 feet long; steam pressure 60 to 80 pounds.

The fuel is gas coke of very poor quality, with 15 per cent. ash, which clinkers on the grate. Sometimes, too rarely indeed, the low price of $10 to $11 for the "long" ton of English coke allows the use of the superior fuel. Anthracite is less adapted, as it springs into small pieces. The worst fuel is a mixture of English coke and gas coke, because the high heat makes the clinkers melt and choke the grate. A large and unobstructed grate is essential for yielding a gas of desirable quality. For the rest, the method of firing or construction of the boiler furnace does not differ from the ordinary practice. An iron pipe 9 inches diameter branches off the iron smokestock and connects with the blower, and the communication with the main stack can be shut off immediately above the branch pipe by a circular damper within easy reach of the engineer. The blower furnishes just enough draught to raise the steam required for the machinery. When the damper is open the draught under the grate increases sufficiently to raise steam for the heating of the different liquids. I never observed a deterioration of the gas by dilution with air sucked downwards through the smoke-stack.

The gas, as I call for the sake of brevity the products of combustion of the coke mixed with more or less free air, is too hot to go at once to the blower. Besides, it was desired to utilize its heat for drying magnesia, allowing at the same time the ashes to settle. The branch pipe from the boiler stack enters a wooden box, the wood being protected from the heat by roofing tin, and in the hottest parts by cement tiles one inch thick. I relied on the nature of the gas which could not support combustion, and was not disappointed, as the woodwork stood well and never caught fire, although I will not deny that in the beginning I felt very nervous on that score. The box was one foot high, and covered with sheets of galvanized iron 7 feet long, 2 feet wide, and was, consequently, 7 feet wide itself. The strong pulsations of the blower made it necessary to fasten every sheet separately, which was achieved by bending the four edges of the sheet so that a pan one inch deep was formed; turning this pan bottom up and caulking the bended strips into recesses made in the wooden planks which every two feet partitioned the long box into chambers with alternating communications. The

whole forms a flat table of galvanized iron with no obstruction whatever, no rivet or bolt having been used, and it never gave trouble. As a dryer, however, it gave less satisfaction than the similar steam dryers to be described later on. If I had to make it over again, I would make the box only one inch high, without any partitions, and collect the ashes elsewhere. Of course, it would be also better although less cheap, to construct it of cast-iron plates instead of wood. For further cooling the gas had to pass through a battery of sixty gas pipes 1 inch diameter, 12 feet long, placed in a horizontal box filled with water, a rather troublesome contrivance, as some tar or similar substance distilled from the coke, and cemented with ashes made a deposit in the pipes difficult to remove. It is remarkable that this deposit contains sometimes boracic acid.

The unstableness of the solution of sesqui-carbonate of magnesia makes quick working imperative. Neither in the laboratory nor on the large scale was it found advantageous to prolong the current of gas more than one hour. In the laboratory the strength of the solution obtained averaged 10 grm. carbonic acid and 6 grm. magnesia per liter, on the large scale 4 to 5 grm. magnesia. The difference is entirely due to the insufficiency of the blower, as results approaching the laboratory results were no rarity, especially at the start when the blower was in better condition. A liberal excess of magnesia over the amount which can be dissolved being necessary, the normal strength of the pulp in the carbonizer (8) has been settled at one-third pound magnesia (MgO) per cubic foot, or 20 pounds for the charge of 60 cubic feet. Strength of pulp and of solution are ascertained by measuring 100 c. c. of either into a flask, adding litmus and so many whole cubic centimeters of a standard solution of sulphuric acid until the red color appears. The strength of this standard solution is so that 10 c. c. neutralize 100 c. c. of the normal pulp. The charge of 60 cubic feet of normal pulp is prepared in (7). One cubic foot of the pulp in (5) holding, as stated before, one pound of magnesia, is to be diluted with two cubic feet of water. Each charge of 20 pounds magnesia or 20 cubic feet of pulp draws consequently about two inches from the reservoir (5). A suitable gauge, which is occasionally changed

according to the unavoidable small variations in the pulp, arriving in (5) informs the engineer when to stop pumping into (7). The water required comes from the water tank (6), and is shut off by a stop with float attached when the proper level is reached. By lifting a large valve the contents of (7) may be discharged into (8) in half a minute or less, the valve stem meanwhile preventing the float from opening the water supply before it is wanted. Each charge of 60 cubic feet of normal pulp remaining one hour in the carbonizer (8), there are made 20 charges in 24 hours (allowing four hours for charging, meal time of the engineer, etc.) and required 400 cubic feet pulp and 800 cubic feet water. Charging and discharging is done without stopping the blower.

The carbonized solution is run off into the settler (9), which is a plain tank 4 feet high 8½ feet diameter, with a row of brass faucets to draw the solution, settled in different heights, into the boiling tank (10). There is no difficulty in obtaining a water-clear solution in (9) when the normal pulp was either faultily prepared or improperly carbonized ; for the voluminous magnesium hydrate has, like the alumina, although in a smaller degree, the power of retaining suspended and organic matter. An undue excess of magnesium hydrate is, however, forbidden, because it abstracts from the solution carbonic acid. Such loss is much more serious than the loss of magnesium hydrate itself. In a properly worked charge the remaining hydrate, which consists only of the coarsest particles which the pulp contained is not sufficient to clear the solution, but it will do so on addition of alum. Each charge in the carbonizer receives, therefore, a pound of alum some minutes before discharging, an important improvement on the original method of applying alum as described above. The time of settling varies but never exceeds one hour; that is, there is always abundant room in the settler as the freshly carbonized charges arrive from (8). The sediment from the 1,200 cubic feet of normal pulp is about 25 cubic feet, is, after a little stirring, fluid enough to run through a funnel pipe of two inches diameter, and is run off every 24 hours, but ought to be removed oftener, as the reducing action of the sediment increases with the accumulation of magnesium hydrate from so many charges.

The boiling tank (10) is 6 feet high 8½ feet diameter. Steam is admitted through an iron nozzle with one quarter inch opening, which enters at such an angle as to produce a rotary motion in the contents. This rotary motion turns a light circular stirrer, which, moving close to the bottom, prevents the settling of the separating magnesium carbonate in the center, as long as steam enters. Steam can also be admitted by a perforated lead coil. This lead pipe is used only when the temperature has reached 200° F., when clogging of the openings by incrustations need no longer be feared. The stirrer can also be turned by hand when the tank is being emptied. There are two such tanks in the plant, each holds 300 cubic feet of the settled solution, beside the increase in volume due to heat and condensed steam, and has, consequently, to work each charge in twelve hours. The manner of heating the solution is of much importance, and the tanks are therefore provided with large thermometers. If the temperature is rapidly raised to the boiling point the separated magnesia will resemble the English article, smooth to the tongue, soft and good otherwise, but only fair in absorbing power; if the boiling is continued the product becomes inferior and resembles the magnesia produced by our discarded process previously described. Magnesia of the greatest absorbing power is obtained by heating rapidly to 160° F., to prevent the separation of the neutral carbonate, and very slowly to 200° F., when the temperature may again quickly rise to 210° F. Then the steam ought to be shut off.

Thus I obtained batches of magnesium, of which one gram required seven grams water before it could be stirred into a stiff pulp. The plant having been erected before I made this observation, an absorbing power for four parts water has to suffice, the English imported article absorbing only three parts. Allowance, however, ought to be made for the deterioration by the long sea voyage. A highly absorbing magnesia is slightly gritty, owing to its crystalline character, and the lumps formed in drying can be converted to powder by a slight pressure of the hand. All these remarks refer only to solutions prepared as described. Solutions of the bicarbonate saturated in cylinders under more than atmospherical pressure may act differently.

The settled solution can be run off one hour after settling commenced. It may be used for slaking the lime or heating the boiler feed water, and contains still some magnesium carbonate, which cannot be made available by continued boiling except by spoiling the quality of the rest. The carbonate in the pulp itself is suspended in fifty times its weight of water, each tank yielding about 150 pounds. The whole yield is 600 pounds, with about 250 pounds of MgO against 400 pounds in the 400 cubic feet of normal pulp. The losses are 1, undissolved magnesia; 2, magnesia reduced from the solution during settling; 3, incrustations in (10); and 4, in the settled solution after boiling.

The pulp is run from (10) to the filtering box (11). This box is 16 feet long, 12 feet wide and one foot high over the false bottom, which is formed by strips of wood nailed to cross-strips fastened to the true bottom. A filter-cloth is spread over sides and false bottom. The pulp is run on a sieve, No. 40, to retain incrustations and other accidental coarse impurities. The filtering presents no difficulties, as the substance filters very rapidly. A filter-cloth lasts a whole season. The pulp from one tank covers the filter-cloth two inches high after the filtration is finished, retains, therefore, fully 12 parts of water for one of substance. It is taken from the filter by iron shovels, wheeled to the steam dryer (12) or the hot air dryer (15), and dumped on the plates.

DRYING, GRINDING AND PACKING.

The drying of the magnesia is one of the most important parts of the process, because the quality of the product is not stable until it is ground and packed. The wet pulp retained on the filter ought to go to the dryers while still warm, and ought to be dried as rapidly as possible. All attempts to withdraw by pressure or suction the 1200 per cent. of water retained by the pulp resulted in spoiling the absorbing power. Drying in the sun, for which the California climate seemed to be so favorable, was also a failure. It has been stated before that the hot air dryers were only moderately effective. An oven carefully constructed, where the flame circulates through iron pipes, and the magnesia

pulp is placed in pans 18 x 18 x 3 inches, which are made of galvanized sheet-iron, gives also only indifferent satisfaction. The cheapest and most reliable apparatus were found to be steam dryers, for which the steam is furnished by the exhaust from the steam engine and steam pumps. They were made as follows: A table or platform 100 feet long, 7 feet wide, was constructed 6 inches above the floor, of tongued and grooved pine boards. Beams of pine 6 x 4 inches were placed around the rim so as to form a pan 6 inches deep. The bottom of this pan was lined with another floor of tongued and grooved redwood boards, which covered the joints of the original floor. A beam being placed along the center line as a support for the cover, and the part of the pan where the steam enters having been protected with iron sheets, the pan was covered with galvanized sheet iron, No. 22 (7 x 2 feet). The sheets were riveted together; the whole sheet, measuring now 100 feet by 7 feet, was turned to bring the flat foot of the rivets up and spiked into the 6 x 4 beams with 20-penny galvanized nails. Joints, nails and rivets having been soldered over, some 4 x 2 scantlings were laid along the rim so as to form a pan two inches deep and bolted to the 6 x 4 beams, etc. There are two such dryers, each costing $200, and yielding two hundred pounds of magnesia in twenty-four hours. The wet pulp is dumped from wheelbarrows in such distances that the pan can be readily covered with a layer one inch high. The limited amount of steam at disposal makes it necessary to reverse the current of steam every twelve hours, so that it first passes under the pan containing half dried material, and thence under the fresh pulp, thus producing perfect condensation. The pulp stiffens quick enough, and the 1,200 per cent. of water are reduced to 300 or 400 within two hours. Afterwards, however, drying proceeds very slowly, because a cushion of dry magnesia interposes between the iron and the still wet magnesia. No further shrinkage or cracking takes place. It will be readily understood now why the pulp ought not to be spread higher than one inch. It would be preferable to charge the pans oftener rather than to increase the thickness, even with an abundance of steam. When cakes are to be made for medical use the pulp is ladled into square frames 6x6x2 inches of galvanized iron.

They are open on top and bottom and are placed on strips of cotton cloth. The frames can soon be lifted off and the cakes handled. As this kind of magnesia requires no great absorbing power the slower drying does not matter. It has already been said that for this magnesia the boiling operation has to be slightly modified. Otherwise it costs about as much to make this kind as the other one.

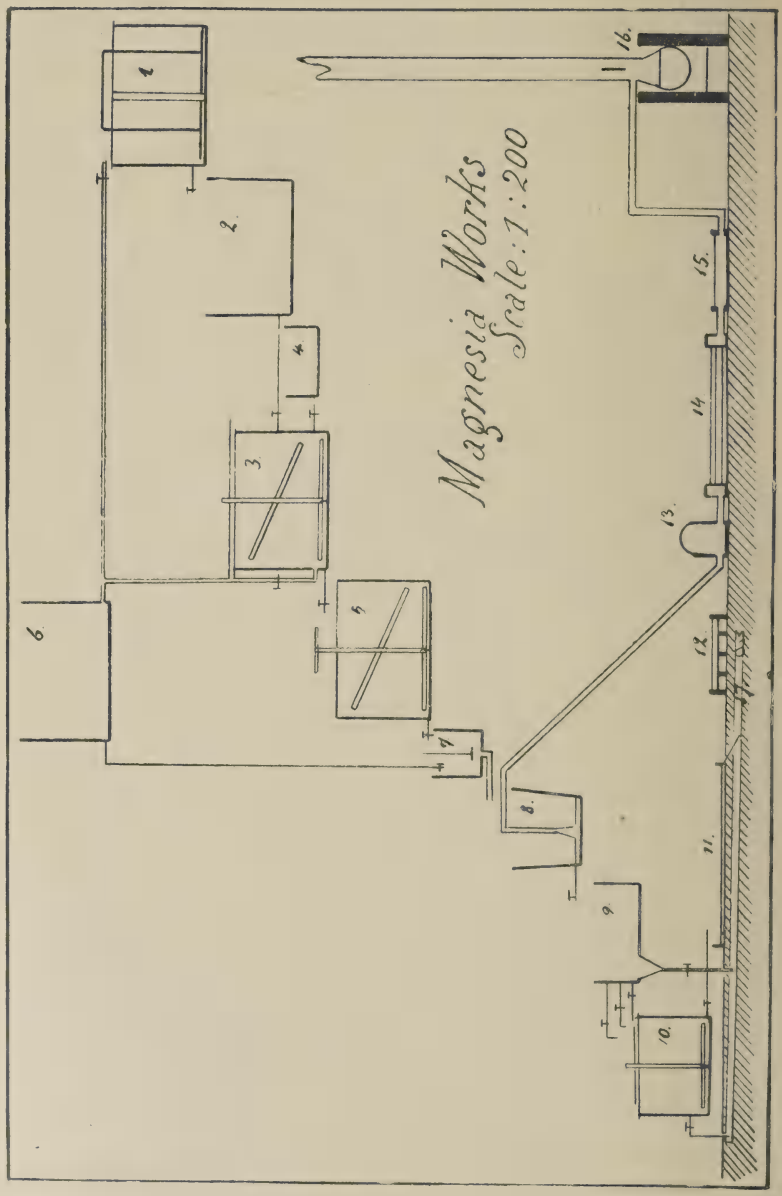
The dry magnesia is shoveled into empty lime barrels and dumped into the hopper of the mill. Here a spiked wooden cylinder makes two hundred revolutions per minute, breaks the lumps and feeds into the mill proper—a kind of coffee mill turning six hundred times per minute by a horizontal shaft. The powder is elevated by a bucket-conveyor into a spacious hopper, whence it is filled into sacks made of light canvas. Each sack when filled and compressed stands four feet high, measures three in diameter, and weighs 150 pounds. The empty sacks get returned, and as the shipments are not to long distances this way of packing is preferable to barrels.

There are employed at the works two engineers, one for day shift, one for night shift, and two Chinamen, of whom one slakes the lime and washes the pulp of magnesium hydrate whilst the other one attends to drying and grinding. The expenses are:

2 Engineers at $2.50 and board	$6 00
2 Chinamen at $1	2 00
20 barrels coke (3,000 lbs) at 50 cts	10 00
3 barrels lime at $1.25	3 75
20 lbs. alum at 2 cts	40
Sundries	5 00
	$27 15

Or about 4½ cents for each pound of the 600 pounds of magnesia made per day.

A reduction of these expenses must be looked for in extension of plant which would not necessitate a corresponding increase in labor or fuel, much of the carbonic acid gas escaping now utilization owing to the insufficient size of the blower.


Magnesia Works
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TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME V.—No. 2.—1888.

MINUTES OF MEETINGS.

REGULAR MEETING.

July 6, 1888.

President Manson in the chair.

The name of Mr. V. Weber, recommended by Messrs. Allardt, Morgan and Compton, was presented for membership; and that of Mr. P. McG. McBean, recommended by Messrs. Manson, Uhlig and Compton, for associate membership.

Mr. Thomas Price read a paper on "The California Geysers." The discussion subsequent to the reading of the paper brought out the fact of the remarkable deficiency of Californian waters and soils in potash.

Mr. Keith narrated some interesting facts connected with safes and locks.

REGULAR MEETING.

August 3, 1888.

In the absence of President Manson, Mr. Luther Wagoner was called to the chair.

Messrs. V. Weber and P. McG. McBean were declared elected; the former as a member, and the latter as an associate member of the society.

Mr. F. Gutzkow read a paper on "The Manufacture of Magnesia from Sea Water in California."

This meeting was one of the most largely attended in the history of the society.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME V.—OCTOBER, 1888.)

THE COPPER MINES OF RIO TINTO, SPAIN.

BY ARTHUR F. PRICE, F. C. S., MEM. TECH. SOC.

Read September 7, 1888.

The principal property of the Rio Tinto Company is situated near the village of Rio Tinto, in the province of Andalusia, Spain, thirty-six miles N. E. of the port of Huelva—communication between the mines and Huelva being maintained by means of a narrow-gauge railway belonging to the company.

Abundant evidence exists that these mines were quite extensively worked by both the Romans and Moors, and in the present operations, old galleries opened by these early miners are frequently encountered.

Originally the property of the Spanish Government, the mines now belong to an English company, who purchased them, it is stated, for something over £3,000,000 sterling. A force of about 4,000 men and children find employment in the various departments, the greatest number of these departments being under the superintendence of Englishmen. The common laborers and miners are paid forty cents a day, whilst the children employed in selecting ore and loading wagons *en route* for the calcining ground receive ten cents for every five tons of ore they handle.

The English employees have comfortable houses provided for them by the company, but the native laborers inhabit squalid huts built by themselves.

Three extensive copper-bearing lodes, known as the South Lode, the San Dianasio Lode, and the North Lode, exist on the property. These lodes run east and west, and the South Lode, at its widest point, measures 180 yards. Tunnels have been driven along the hanging wall, and from these tunnels galleries have been extended and connected. On a portion of the South Lode the top ground has been removed, forming an immense open cast from which large quantities of ore have been removed. The principal copper mineral found is chalcopyrite, but tetrahedrite and other ores also exist.

It has been estimated that 6,000,000 tons of copper-bearing mineral exists in the three lodes, which, at the present rate of output, gives 150 to 200 years of copper in sight.

An active oxidizing action is constantly going on in various parts of the mine, and the sulphate of copper resulting from this reaction is leached out by the large quantity of water which percolates through the mine during the rainy season, and constitutes a considerable source of metallic copper.

Treatment of the Ore.—The ore is carried from the mines in large wagons drawn by locomotives, and dumped onto the various selection-grounds. A large quantity of mineral carrying from 3% to 3.5% metallic copper is shipped to various points in Great Britain, Germany and the United States, where it is first utilized for the manufacture of sulphuric acid, and the copper subsequently extracted from the burnt pyrites. The amount of pyrites thus delivered during the past year amounted to 385,892 tons, from which was obtained 7,920 tons of metallic copper.

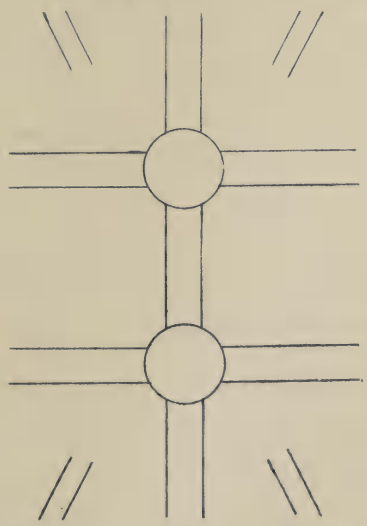
The richer mineral, carrying 7% copper and over, is selected out for treatment in the blast furnaces, as are also minerals rich in galena and silica. In these furnaces the ore is smelted to a regulus, and this regulus cast into moulds and shipped to England.

The mineral remaining after selection has about the following composition:

Sulphur	48.00 %
Iron	40.74 "
Copper	3.42 "
Lead	0.82 "
Lime	0.21 "
Magnesia	0.08 "
Arsenic	0.21 "
Silica and Insoluble	5.50 "
Oxygen, water and loss	1.02 "
	100.00 %

The coarser lumps of this material are carried to the calcining ground; the "smalls," or finely-divided mineral, being reserved for subsequent treatment.

In constructing the heaps for roasting, a ground-work of rough stones or large lumps of ore is built in the following form, and on this the ore is piled:



When the heaps are formed they are lighted by means of a log of wood, after which the combustion continues of itself.

During this operation the copper sulphide is oxidized to the sulphate, and the iron converted into ferrous and ferric salts, large quantities of sulphurous anhydride being given off.

So great a nuisance has this become to the surrounding country that early in the present year the Spanish Government issued a decree suppressing gradually all open-air calcinations at these mines. The decree requires that from the first of January, 1889, all open-air calcinations shall be reduced one-fourth; from the beginning of 1890 by one-half; and from the beginning of 1891 shall cease altogether. The company, however, proposes to use all possible measures to prevent the enforcement of this decree.

To complete the calcination from twelve to fourteen months are required, after which the material is carefully examined, and lumps of ore in which the copper has become concentrated are put to one side for treatment in the blast furnaces. The calcined material is now thrown into large wooden tanks furnished with a false bottom, and water introduced. At the expiration of twelve hours the water, charged with sulphate of copper and iron salts, is drawn off and fresh water introduced—this being repeated until no further reaction for copper is obtained.

The copper liquor obtained from the first lixiviation of the calcined material is too strong for immediate treatment, and is, therefore, pumped through wood-lined pipes to a reservoir, whence it is drawn off little by little and mixed with poorer liquors. It is also used for acting on the "smalls," mentioned above, which are placed in tanks without previous calcination, and by the action of the strong liquor yield up a considerable percentage of their copper contents.

The calcined material, deprived of its copper by lixiviation, serves a useful purpose in rendering it possible to obtain the copper from that portion of the "smalls" not treated by the first liquors. The finely-divided state of these "smalls" will not admit of the draught necessary in the calcination of ores; but when a pile is constructed of alternating layers of the material left after lixiviation and of "smalls," a reaction occurs after

a lapse of time, whereby the copper in the "smalls" is oxidized and rendered soluble in water. The cost of putting the copper from what would otherwise be a waste material in a merchantable form, and on the English market, is estimated at about $100 per ton of copper produced.

The copper liquors, from whatever sources derived, are led into long, narrow tanks containing bars of pig-iron, old rails and iron scraps, arranged so as to admit of a free passage for the liquors. The partially exhausted liquor, on leaving the tanks, is repeatedly pumped back, passed through the calcined ore, and through the tanks again. When the stream has run through a tank for from fifteen to sixteen days it is diverted, and the tank cleaned out. The copper is now found precipitated on the iron in metallic flakes, and is easily removed. This precipitated or cement copper is washed with dilute sulphuric acid to remove the graphite derived from the iron, and to eliminate arsenic, after which it is washed with clean water and spread on the drying floors. The unwashed precipitate contains about 76% copper; but after washing and drying, contains from 94% to 96%. The mud remaining in the tanks frequently contains about 8% of finely-divided copper, and it is, therefore, allowed to settle in a separate vat, the water drawn off, and the mud then pressed into balls, which are dried in the sun and calcined, when they are found to contain from 18% to 30% of copper. The calcined material is subsequently treated in blast furnaces.

Experiments have been made with a view of dispensing with calcination by utilizing the old liquors from which the copper has been precipitated. These liquors are rich in iron salts, and by passing them through chlorine towers ferric chloride is readily formed, and this acting on the raw ore places the copper in a soluble form. This process, however, is exceedingly slow, and has not been extensively employed.

Further experiments have been made by introducing the copper liquor, in the form of a fine spray, at the top of a large tub, and simultaneously introducing sulphuretted hydrogen at the bottom. This process was, however, a failure, as the precipita-

tion was slow, and the precipitate, when obtained, difficult to deal with.

The amount of metallic copper manufactured at the mines during the past year amounted to 17,813 tons, making, with that reduced from the pyrites shipped away, the total product for the year 25,733 tons of metallic copper. The pyrites extracted from the mines during the year amounted to 1,182,-438 tons, enabling the company to declare a dividend of £325,000, or 10%. During 1887 the average price received by the company for their copper was £48 per ton; but under existing contracts for the next three years they will receive an advance on this of some £20 per ton, and they expect to produce 26,000 tons of metallic copper per annum. This will make the annual profits of the company over £500,000 per annum.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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(VOLUME V.—OCTOBER, 1888.)

NOTES ON THE WALNUT GROVE DAM.

BY LUTHER WAGONER, MEM. TECH. SOC.

Read October 5, 1888.

This dam is situate on Hassayampa Creek about thirty-five miles south of Prescott, Arizona; its elevation above sea level is about 3,500 feet. The drainage area above the dam is 390 square miles; annual rainfall not known, but supposed to average 16 inches. The dam was built to store water, principally for some alleged rich placers on the mesa some eighteen miles below the dam. Cattle raising and irrigation were also secondary considerations. Some pine timber growing at an elevation of 6,000 to 8,000 feet on the Bradshaw Mountains is the only available source of lumber supply, but the quality is very poor, knotty and unsound, and very brittle.

The country rock at the dam site is a coarse-grained granite, easily quarried. The high price of good lumber, cement, and supplies determined the choice of methods of construction.

The history of the construction of the dam is one full of blunders, mainly caused by the officers of the company in New York. Work was commenced on company account by Prof. W. P. Blake, who carried a wall across the cañon to bedrock through

about 20 feet of sand and gravel. What his intentions were to do next is not known, as no records were made or kept by the company's officers at the dam. He was succeeded by Col. E. N. Robinson as Chief Engineer, and the work was contracted for by Nagle & Leonard of San Francisco. I presume the cross-sections and general methods of construction were fixed by Mr. R. Under him the dam was commenced in the rear of the Blake wall, and was described in the specifications as being composed of front and back walls 14 feet at the base and 4 feet at the top, with loose rock filling between. (See fig. 2.) The dam to be made water tight by a wooden skin or sheathing.

Quarries were opened by the contractors upon both banks of the stream above the top of dam. "Coyote" holes from 8 to 15 feet deep were charged with low grade powder (4° nitro glycerine), and the stone dislodged in large amount. These holes usually followed the intersection of two fissures at an acute angle; sometimes a third fissure would cross the others, thus forming a triangular hole and making it easy to remove by splitting the small triangle of rock. The stone was loaded upon cars, having the bed inclined at about 15°, and were lowered on the dam by a bull-wheel and brake, a three rail railroad being laid on trestle across the dam, height from 10 to 15 feet. On the slope midway was a turnout so as to allow the loaded car to pass the empty car. The loaded car was unhooked on the level and run out and dumped and returned above by the next loaded car. The legs of the trestle were left in the wall, only the caps and stringers were raised. During the first stages of construction derricks were used to distribute the larger stones; later the center was kept high and the stones for the wall were moved by bars. The effect of this upon the stability of the dam is bad because it tends to form curved beds whose slope makes an acute angle with the direction of the resultant pressure.

The company purchased a saw mill and cut the lumber for the dam, buildings, etc., and the skin was put on by contract.

Cedar logs 8 to 10 inches in diameter, by 6 feet long, were built into the wall on the upper face, and projected out one foot. Vertical stringers 6″ x 10″, of native pine, were bolted to the

logs; the stringer were about 4 feet apart; at the joints of the 6 x 10 stringers a cedar log was built in the wall about two inches above the top of the stringers, and two 4 x 10 splice pieces bolted through the log and spiked to the 6 x 10 pieces with galvanic boat spikes, completed the joint. Upon the main wall of the dam a double planking of 3-inch boards was laid, having a tarred paper put on with tacks between the planks. The outer row of planks was caulked with oakum and painted with a heavy coat of paraffine paint (refined asphaltum, or maltha dissolved in carbon bisulphide). The junction of the plank skin and the bed rock was secured by Portland cement.

Through the dam is a culvert 3 x 4 feet inside about the level of the old creek channel; this is boarded with 3-inch plank inside and has a gate to draw off the water and waste it. (See fig. 1.)

The water for use is taken into an inlet tower. (See valve tower, fig. 2.) This tower is built of 8 x 8-inch timber, 8 feet long, notched one-half on each end, secured by a $\frac{5}{8}$ rod through each corner, the joints caulked with oakum, and the outside painted with paraffine paint. There are two inlet valves, one at the base of the tower and one 20 feet higher. The valves are of wood, sliding upon wood, area pressed upon about 15 square feet; a 6-inch square wooden stem runs up on the outside of the tower, and above the platform on the tower where the mechanism is placed to open and close the valves. This is shown in fig. 3, where A and C are pinions, B a spur wheel, D the valve stem, having a rack on the side next to C, and an iron plate on the side E. E is a roller to hold the stem in position. All this gear is mounted upon a massive iron bed-plate resting upon a wooden frame upon the platform. On both ends of the shaft A is a crank; two men could give a pull on the valve stem of about 700 pounds with the above described gear. With 30 feet of water pressure they could not move the valve, perhaps for the reason that the load to overcome was about $15 \times 30 \times 62.4 \times 40\ \% = 11,232$ pounds. The machines (three of them), were designed by one of my predecessors, and were erected despite of my advice that they would not work. The reason assigned for erecting them was, "they were designed by an engineer and must work."

From the valve tower the water is conveyed in two 20-inch iron pipes to the gate house below the dam where each pipe is provided with a gate. The pipes go through a tunnel, part of the way through a spur, and of rubble, arched the remainder of the way. With 70 feet of water above bed-rock the dam leaked 141 inches. (1.6 cu. ft.=1 inch.) Various theories were advanced for the cause of the leak: one was, that settlement of the dam had forced an opening of the junction of the inclined and horizontal skins; and another was, that it leaked all over the whole surface. The extreme right hand skin below the bed of the stream (fig. 2), is made of but one plank. The machinery for draining the water was inadequate, and the men who did the cementing to bed rock assured me that they worked in four feet of water, and that they did not go to bed rock, while per contra the sub-contractor (Whoop 'em up, Jack) for the work assured me it was well done. The probable cause of leakage, I believe, is all three of the reasons named.

Regarding the stability of the tower I think the pressure too great upon the timbers 8″ x 8″ x 8′ to be safe, and of the dam as originally built during a month's interval, when there was no chief engineer, some very bad work was done (see fig. 2), left side of wall, near middle. I advised the company to cut a large waste way and put the loose rock below the dam to strengthen this weak place.

The contract for the dam proper was for 46,000 cubic yards, lumped at $2.40 per cubic yard. The skin and cementing was extra. Lumber cost about $15 at the dam; $2,000 freight was paid on $1,000 worth of cement purchased in San Francisco.

Labor was quite unreliable, perhaps owing to the presence of saloons and gambling shops, and the totally inadequate provision made for the comfort of the men by either the company or the contractor. This coupled with the intense heat, poor water and food, did not offer sufficient inducements to attract a sober and reliable class of workmen, a point too often overlooked in the construction of a large work.

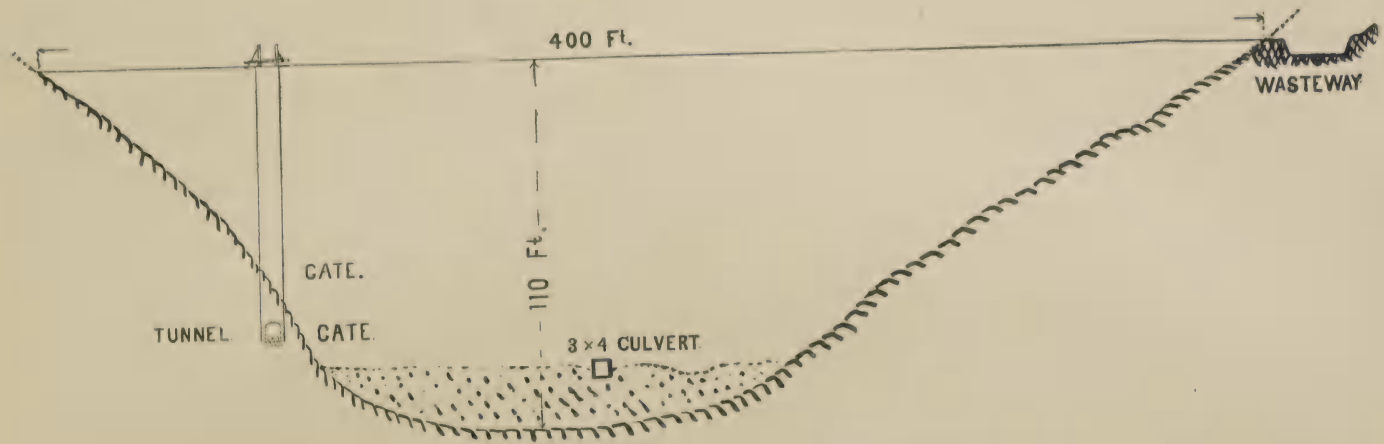
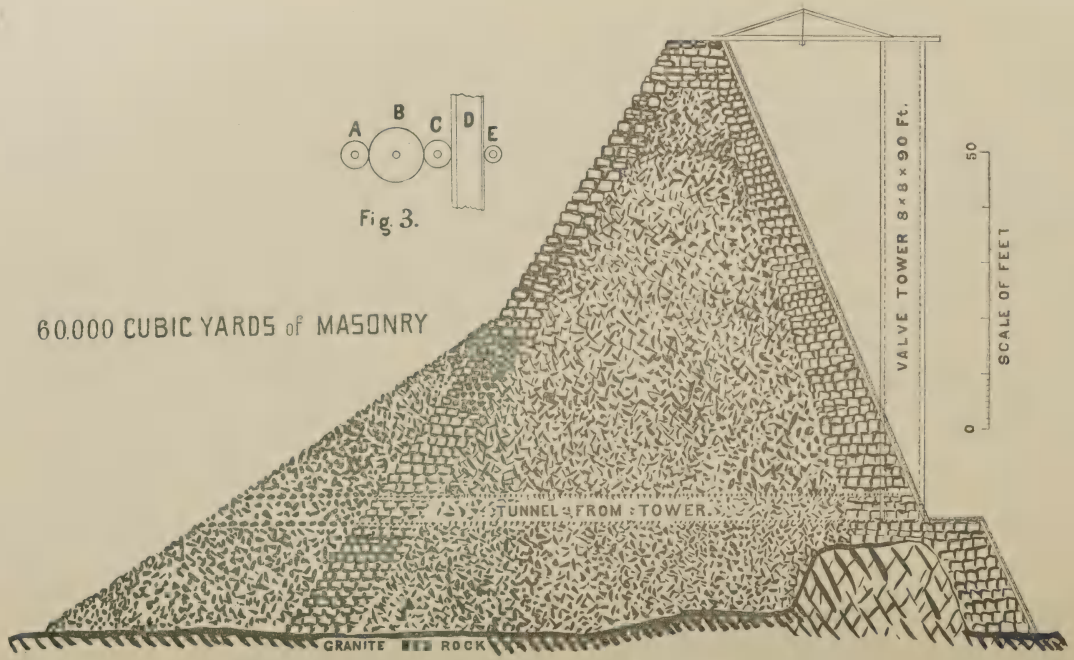


Fig. 1

WALNUT GROVE DAM, ARIZONA TER.

PROFILE



CROSS SECTION THROUGH THE DAM

Fig. 2.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME V.—No. 3.—1888.

MINUTES OF MEETINGS.

REGULAR MEETING.

September 7th, 1888.

President Manson in the chair.

The ballots on the name of Mr. Herrmann Kower were counted and that gentleman declared elected a member of the Society.

Mr. A. F. Price read a paper on "The Copper Mines of Rio Tinto, Spain."

Mr. E. J. Molera moved that a committee be appointed to draft suitable resolutions in memory of the late George J. Specht, which being duly seconded, Mr. Manson appointed the following committee: E. J. Molera, G. F. Allardt and F. Gutzkow.

REGULAR MEETING.

October 5th, 1888.

President Manson in the chair.

Mr. Luther Wagoner read a paper on the "Walnut Grove Dam, Arizona Territory." In the discussion which followed,

other dams were described by Messrs. Vischer, Allardt and Molera.

Mr. Luther Wagoner stated that through the courtesy of Lieut. Gilmore, U. S. Government Inspector of Steel for the Cruisers "Charleston" and "San Francisco," he would soon make a series of tests of twisted bars of iron and steel, and that the results of his experiments would be duly reported to the Society.

The committee appointed to draft suitable resolutions of respect to the memory of the late George J. Specht presented the following:

Members of the Technical Society:

In compliance with a resolution passed by you at our last meeting, the undersigned have the honor to submit the following:

Our lamented fellow member, and ex-Vice-President, George J. Specht, was born in Eutin, Holstein, Germany, on the 19th of April, 1851, and graduated at the same place at the Gymnasium, or Latin School.

He served with the German army during the Franco-German war, and at the end of the war began his studies in civil engineering, graduating at the Polytechnic School at Graz in 1874.

His practice as engineer in Europe was on the Austrian N. W. R. R., afterwards on the Crown Prince-Rudolf R. R. in 1875, and at the Gothard R. R., in Switzerland, until February, 1877, when he came to California.

He arrived in San Francisco in the summer of the same year, and introduced the system of copying maps and drawings by the Ferro-prussiate or blue process, and other improved methods in engineering practice used in Europe, and but little known here at the time.

His first engineering work in America, was as assistant in making a topographical survey of the Cooper ranch, in the Salinas Valley, and in that place he opened an office as Surveyor and Civil Engineer.

Soon after he moved to San Francisco and opened an office together with Messrs. Allardt, Von Leicht, and other civil engineers. He was appointed engineer of the Sutro Tunnel in 1879 to 1881, when he returned to San Francisco, and at different times was employed as engineer of the Sutter County Land Company, and assistant engineer of the Spring Valley Water Works.

At the time when he was afflicted with the malady which caused his death, he was assistant in charge of the San Diego drainage system under Col. Waring.

Our Society is specially indebted to our lamented colleague as the principal promoter and founder of our institution. He was of an enthusiastic temperament, and had the magnetic power of transmitting it to others, and owing, mainly, to his energy and perseverance it was possible to gather to-

gether the scattered elements that in a new and busy country are so difficult to join in a social pursuit.

As our first Chairman *pro tem.*, Vice-President, and member of the Executive Committee, his services have been most valuable, and we all remember with pleasure his directness of purpose, absolute integrity, and the unselfishness with which he discharged the duties confided to him.

Besides his practical work as an engineer, he always endeavored to inform himself of the progress made in the several engineering branches both on this continent and in Europe, and contributed several valuable papers to our Society, and scientific journals of America and Europe, making much advance in the engineering science known.

It is, then, with the keen pain and regret of the loss of such an honorable man, able engineer, and invaluable member of our Society, that we submit the accompanying resolutions:

Resolved, That the Technical Society of the Pacific Coast recognizes in the death of our ex-Vice-President, George J. Specht, the termination of a life of excellence and great usefulness.

That his death is an irreparable loss to this Society.

That his generous character and intelligent services entitle him to our gratitude.

That we sympathize with his family in their bereavement, and participate in their grief.

Resolved, That a copy of these resolutions be transmitted to the family of the deceased and be spread upon the records of this Society.

(Signed:) E. J. MOLERA,
G. F. ALLARDT,
F. GUTZKOW,
Committee.

On motion, the above resolutions were unanimously adopted.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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(VOLUME V.—DECEMBER, 1888.)

THE SWAMP AND MARSH LANDS OF CALIFORNIA.

BY MARSDEN MANSON.

Read Nov. 2d, 1888.

[NOTE.—It is not considered necessary to issue a map with this paper, as any of the ordinary maps of the State will serve. The best for general reference is that published by the United States General Land Office in 1885; and for the valley lands, that published by the State Engineering Department in 1887.]

The objects of this paper are:—(1) to show the singularly systemless manner in which an important matter has been and is now being treated; (2) to collect and put of record certain data that is being lost, at least to the public; (3) to awaken sufficient interest in the question to ultimately place the reclamation of swamp and marsh lands on a practicable footing; (4) to make a few suggestions, in the hope that the subject may receive that attention from the State and public which its importance merits. The hope is expressed that there will be a full discussion of the subject, to the end that much important information and data may be added.

Through the Act of Congress of September 28th, 1850, popularly known as the "Arkansas Act," there were granted to the State of California some $1\frac{3}{4}$ to 2 millions acres of "swamp and overflowed land," or from 2,300 to 3,100 square miles. The conditions of this grant were simple; namely, that the land should be *reclaimed;* and the State, in accepting these lands,

is under the obligation to reclaim all that can be practically reclaimed.

Not until 1855 did the State seem to realize the magnificence of this grant, and prepare to utilize it. In that year a law was enacted allowing the land to be taken up in 320-acre tracts at $1.00 per acre. No reclamation was required if paid for in cash, but if on a credit of five years, one-half was to be reclaimed, or the claim was to be forfeited. (See Statutes of California, 1855, p. 189.) Even the credit system thus established did not lure many to invest, as there were only a few thousand acres sold in the three years during which the law remained in force.

In 1858 the above plan was amended by abolishing the credit system, and placing the proceeds of cash sales to the credit of a swamp land fund, but made no provision for the very essential matter of reclamation. (Stat. of 1858, p. 198.)

Again, in 1859, amendments were made increasing the limit from 320 acres to 640, and re-establishing the credit system by requiring 20% cash to be paid, and leaving the remaining 80% on a credit of five years. (Stat. 1859, p. 340.)

These laws were still further amended in 1861. A general "system" of reclamation was adopted. A Board of Swamp Land Commissioners was created, engineers employed, and in the immediately succeeding years some $567,483.86 were expended. (Stat. 1861, p. 355.)

These laws did not permit the acquisition of lands in sufficiently large bodies to attract capitalists to undertake their reclamation; so, in 1868, an act was passed repealing all laws just reviewed, but reënacting their general terms, except that no limit whatever was placed upon the area any one might take up. (Stats. Cal., 1868, pp. 507–530.)

The legislature either did not know what it was doing, or knowing, did not care to correct. Through this "law" the State parted with the greater portion of her magnificent holdings. About 1,000,000 acres were taken up in bodies of from a few hundred to 98,120 acres, or over four townships—153 square miles in one body!

Many of the parties thus acquiring these lands made strong, but ill-advised and misguided efforts, to reclaim their possessions. Some have impoverished themselves in such efforts.

The law at present limits the area which can be taken up by any one person to 640 acres.

These lands may be divided into three classes:

I. Salt Marsh, or lands bordering the bays, estuaries, etc., and subject to tidal overflow of salt or brackish water.

II. Swamps of Low Outfall, or such as border the lower reaches of Sacramento and San Joaquin rivers.

III. Elevated Swamp Lands, having an available outfall, or such as border large lakes, and mountain swamps.

Portions of each of these classes have been partially or entirely reclaimed, but by far the greater portion of each is in its original condition, and but a small percentage of the gross area has been brought under permanent cultivation. There are no reliable statistics as to reclaimed areas, as many "districts" which have been reported "reclaimed" (and so stand upon the State records) have since been abandoned.

Large areas were "reclaimed" only so far as to secure the patent from the willing hands of the State officials.

Again, large areas which were classified as "swamp and overflowed lands," are the best alluvial lands in the State.

In the face of this state of affairs, it is not possible to properly divide the lands, nor to ascertain their areas and conditions. The figures given are, therefore, only approximately correct.

I. Salt Marsh, or lands bordering the bays, estuaries and rivers, and subject to tidal overflow. These aggregate about 320 square miles, or 203,660 acres, distributed approximately as follows:

Around San Francisco Bay (proper)	76,800 acres.
Around San Pablo Bay	51,200 "
Around Suisun Bay	64,000 "
(Report of Col. G. H. Mendell, 1880.)	
Around Humboldt Bay	5,000 "
Around Landings and False Bays	4,160 "
Various Localities	2,500 "
(U. S. Coast Survey Charts.)	
Total	203,660 "

The surface of these lands is generally a fine, dark, alluvial deposit, overgrown with samphire and salt grasses, merging into flags and tules as the water becomes brackish or fresh. The subsoil is soft "harbor mud" of varying thickness, and, lower down, sand, gravel or clay; or intermixed strata of these. In some localities the sand and gravel have been cemented into "hard-pan." The soft mnd is sometimes too soft to sustain the weight of embankments, in which case levee building, or railroad grading becomes difficult from the breaking of the crust and the sinking of the embankment.

These lands exist in isolated areas of from a few hundred acres to large tracts embracing thousands of acres. Being separated by adjacent high lands, and fronting on the bays, their reclamation can be reasonably undertaken separately. The maximum rise and fall of tide being known, the reclamation becomes to the engineer a simple problem of, first, shutting out flood tides; and secondly, storing and removing seepage and drainage waters. There are no vast volumes of flood waters to be considered, no complicated system of valley drainage to study, as is the case in the marsh lands bordering the lower rivers.

Still, the reclamation of salt marsh lands has but rarely been attempted, although such reclamation is by far more certain and easy than that of river marsh lands of low outfall. The most notable instances of salt marsh reclamation are at Novato, near San Mateo Creek, at the mouth of San Pablo Creek, at the mouth of Napa River, and a few other minor areas at various points.

The most successful and systematic work of this nature is at Novato, in Marin County, under Mr. J. W. Ferris, C. E., Member Technical Society of the Pacifie Coast.

At this point the reclamation and drainage is accomplished by:

1st. Primary ditches (*a*) back of and parallel with the dykes, and (*b*) running back into the lands; both provided with tide-gates opening outwards and automatically shutting out rising tides.

2d. Secondary, ditches subdividing the lands along the most advantageous lines.

3d. Tertiary ditches, which are simple surface-drains, a few hundred feet apart, and draining into the secondary ditches.

The primary and secondary ditches are most cheaply constructed with dredging or ditching machines, and the tertiary with the ordinary plow and road-scraper.

At San Mateo the lands have been dyked in, and ditches made across the lands, but at the time of examination no tertiary drains of moment had been made. The flood waters of San Mateo Creek have been used to warp up and leach the salts out of the lands. A large number of artesian wells have been sunk. The discharge from these wells is used to aid the creek waters, and for watering stock. The flow from them is sluggish and extends to but a few feet above the soil.

Upon drying and exposure to air, the soil of these marshes becomes friable for a few inches in depth, and, unless very heavily charged with sea salts, will yield the coarser grasses and grains in two or three seasons. The mistake of too deep plowing turns up the stiff baking clays, and has in instances caused the failure of crops and the consequent condemnation of the engineer for wasting money on lands which were found to be valueless after reclamation. The mistake here was in the subsequent treatment. Deep plowing on these lands must be done by gradually plowing an inch or two deeper each year. The writer has seen great slabs of baked clay resist for years the pulverizing effects of exposure, when the mere scratching of the soil would have produced good barley hay.

It is difficult to ascertain the amounts which have been spent on the salt-marsh lands. Of the 203,660 acres heretofore given, not one-tenth has been reclaimed, and the remaining nine-tenths is in its original condition, serving only as coarse pasture lands. When reclaimed it readily pays an interest, over and above cost of cultivation, on a valuation of $100.00 per acre; so that it represents a possible value of $20,000,000. This figure conveys an idea of what can reasonably be spent in reclaiming these lands.

II. SWAMPS OF LOW OUTFALL.

The lands of this class constitute those large areas situated on the lower San Joaquin and Sacramento rivers and their tributaries; and embrace the islands and adjacent swamp lands on the San Joaquin from the mouth of the Stanislaus to New York Landing, and whose elevation is from 5 to 18 feet above low tide in Suisun Bay; and the low lands of the Sacramento and tributaries known as the Yolo-Solano Basin, the Pocket, American Basin and the Sutter Basin. Their mean elevation above low tide in Suisun Bay is about as follows: Of the Yolo-Solano Basin, 12 feet; of the American Basin, 20 feet, and of the Sutter Basin, 22 feet. (These elevations were estimated by Mr. C. E. Grunsky, Assistant State Engineer.)

The aggregate area of these bodies of land is over a million acres, which have been, and are now, the theatre of large operations of drainage and reclamation.

Most of these operations have been unsuccessful. Where successful, it has been from a combination of vigorous work and favorable circumstances.

The subject of draining and reclaiming these lands is so intimately connected with the problem of treating the rivers that it is impossible to discuss the one without bringing in the other; hence no apology is offered if the rivers appear too prominent.

The swamp lands of the San Joaquin are materially different from those of the Sacramento, in the more extensive occurrence of a peaty soil and subsoil. This feature is not so prominent in these latter lands. This is due to the greater amount of alluvial matter brought down by the Sacramento and its tributaries, whose more frequent floods and heavier rainfall cause a higher rate of sub-aerial denudation in the upland and mountain areas, draining through the basin lands.

The depth of this peaty soil is not definitely known in the lower portion of the San Joaquin. Where known, it varies from a few feet to sixty or more feet. The stratum below the peat is generally clay, merging into "hard-pan." The varying depth of this peaty stratum can best be appreciated from the following data:

Locality.	Depth of Peat.
Robert's Island	4 to 34 feet.
Union Island	4 to — "
Rough and Ready Island	4 to 8 "
Bacon Island	15 to 34 "
Mandeville Island	20 to 25 "
Lower part of Staten Island	20 to 25 "
Bouldin Island	13 to 42 "
Ryer Island	8 to 16 "

Experience in several localities has shown that where peat is over 25 or 30 feet deep it is very difficult to construct levees upon it; and over the latter depth impracticable. In the shallower depths it is possible to compress or displace the peat and construct embankments. The experience in this peaty soil has been gained at great expense, and is very valuable, showing the necessity of thorough examination by competent authority before any attempt to carry out reclamation. In some instances the lowering of water has caused the weight of the soil to compress the subsoil several feet. In others the crust of peaty and alluvial soil rises and falls with the tide.

In those localities where alluvial deposits predominate the soil is sufficiently firm to hold the weight of the embankments, and operations in these localities have generally been more successful.

III. ELEVATED SWAMPS, HAVING OUTFALL,

Or such as border the upper rivers, lakes and mountain swamps.

The largest areas of these lands are at the head of the San Joaquin Valley. It is impossible to give their acreages, as these vary according to the elevation of water in adjoining lakes. Particularly is this the case with Tulare Lake. Here successive years of low rainfall, and the diversion of water for irrigation, have lowered the surface of the lake many feet in the last decade; and as the lands slope only a few feet per mile, many thousand acres have been uncovered, and the head-gates of proposed irrigation works have been left several miles out on the land.

Successive lines of vegetation and the legends of Indians go

to show that this lake is subject to periods of rise and fall, extending over years. It is possible that its present area, 320 square miles, (as given by maps published by the State Engineering Department), will enlarge. In 1873 the area was 687 square miles. (See Report of Board of Commissioners of the Irrigation of the Valleys of the San Joaquin, Tulare and Sacramento. Washington, 1874.)

Similar but smaller bodies of land occur around Kern and Buena Vista lakes.

In the Sacramento Valley the larger areas are the Colusa Basin, having an average elevation of 35 feet; and Butte Basin, 65 feet. The successful reclamation of these lands depends upon a thorough system of river improvement and drainage canals. Considering their great fertility, advantages of climate and the cheapness of work with recent dredging and ditching machinery, it is surprising that work of this character has not been inaugurated on a scale commensurate with the problems involved.

MOUNTAIN SWAMPS.

The aggregate area of these lands, as shown on the map issued by the General Land Office in 1885, is about 156,800 acres. These lands do not rank as high in fertility as the valley marshes, nor is their climate so warm. They occur at altitudes of from two to four thousand or more feet, and in isolated areas of from a few hundred to thousands of acres. Nearly all are in the mountain drainage basins of Feather, Sacramento and Klamath rivers, and in the northeastern part of the State lying in the Humboldt Basin. Many of these areas are capable of thorough and cheap drainage; and of the swamp-land districts organized in the mountains, many are recorded in the State Surveyor-General's Reports as "reclamation complete." These, however, are generally the smaller areas of only a few hundred or a thousand or two acres at most. In some of the large bodies, where tules, flags, etc., occur, the soil is very thin, the roots being matted to bare rocks with a mere film of soil. In other localities the soil is a very coarse slaty or granitic sand; and, again, where the surface is lava, there is in some places

very little soil. Under these conditions, a very close and critical examination has to be made before the results of reclamation can be determined.

These mountain swamps are generally produced by one of two causes: 1st. The partial or complete filling up of lakes, in which case there is generally an outfall, more or less available. 2nd. The drying up of a lake, in which case there is a very poor outfall, or sometimes none, and the reclamation is dependent upon the rainfall.

Under the first head there are large and valuable areas whose reclamation would be highly remunerative. Many of the smaller tracts which have been reclaimed are valued at an average of $40 to $50 per acre. Taking the smaller figure, and estimating the available lands of this class at 125,000 acres, they represent a value of $5,000,000.

EXPENDITURES.

The expenditures which the writer has attempted to trace have been upon the II Class of lands, or the swamps bordering the lower rivers. Upon these lands and the adjoining river channels vast sums of money have been expended, much of which is generally acknowledged to have been without adequate return. Instead of treating the subject as a whole, which it is, it is divided into several hundred "reclamation" or "swamp land districts." These districts, as a general thing, have natural boundaries, although some are arbitrarily bounded by property or other lines. The authorities of each district have been supreme so far as the works in that district are concerned, and have located and built them in many instances irrespective of the effect upon the river or other lands. The prime object being the *protection* of the lands of their district *according to their ideas.*

We will review these expenditures.

STATE FUNDS.

Since the initial operations, commencing in 1855, the State of California has spent the following amounts:

General Swamp Land Fund	$ 152,040 51
District Swamp Land Funds	547,546 74
State Engineer's Department, since May, 1878	259,023 70
Drainage—District Law of 1877	20,000 00
Act to Promote Drainage, 1880	699,577 25
Swamp Land Commission. (22d Ses., Vol. 4.)	1,470,000 00
Total	$3,148,188 20

The Act of March 12th, 1868, transferred all funds deposited to the credit of the district funds, to the various authorities of the counties in which the lands were situated, and it is difficult to trace the sums expended through the scattered county records.

The United States have spent or placed available for the closely allied works of improving the navigation of Sacramento, Feather and San Joaquin rivers the sum of $654,747.89.

So far as the writer has been able to trace them, the expenditures of the districts have been as follows:

SACRAMENTO DISTRICTS.

Jacinto to Knight's Landing	$1,350,000 00
Reclamation Districts Nos. 108, 124, 494.	
East Bank Jacinto to Feather	1,250,000 00
Feather and Yuba Rivers	2,513,000 00
Grand Island	1,000,000 00
Andrus Island	241,500 00
Ryer Island	42,000 00
Sherman Island (approx.)	250,000 00
	$6,646,500 00
On the Sacramento and American Rivers, from Feather River to Grand Island, including Sacramento and Washington (approx.)	1,500,000 00
	$7,146,500 00

SAN JOAQUIN DISTRICTS.

McMullen District	$ 10,000 00
District No. 17	96,000 00
Small Districts near Stockton	138,000 00
Roberts Island	750,000 00
Bouldin Island	238,060 00
Bacon and Mandeville Islands	370,000 00
Union Island	1,250,000 00
Staten Island	607,500 00
Twitchell Island	132,000 00
Rough and Ready Island	99,750 00
	$3,891,131 00

RECAPITULATION.

By the State	$3,148,188 20
By the United States	654,747 89
Sacramento and tributaries	7,146,500 00
San Joaquin and tributaries	3,891,131 00
Total	$14,840,567 09

Of the $3,000,000,00 spent by the State, there is not a very substantial result. The largest single item is that expended by the Swamp Land Commission, and if included with the sums expended under the General and District Swamp Land Laws aggregates some $2,000,000.00 or more. These expenditures were made principally to secure the land and before the rivers had been studied or even thoroughly observed. Whatever practical results have been obtained may be accounted for in part, by a portion of the existing hundreds of miles of levees.

The Sacramento Drainage District Law of 1877 resulted in a very able report from Col. Isaac Smith, C. E., and Mr. J. C. Pierson, Mem. Tech. Soc. Under this law $20,000 was expended, and it is to be regretted that the recommendations then made have not been followed.

Of that unfortunate fiasco "The Act to Promote Drainage," it is unnecessary to speak, further than to regret that it has

delayed legitimate engineering action on behalf of the State for at least a decade. It will be hard to induce the legislature to make even a small appropriation for the improvement of California rivers with this costly monument to ill advised action staring them in the face. Before the law was declared unconstitutional by the Supreme Court the promoters had succeeded in spending $699,577.25. As a result, however, many levees then existing were raised and strengthened and valuable experience gained in other lines.

The results of the appropriations for surveys and examinations, etc., by the State Engineering Department have not yet been fully published, although a vast fund of data has been collected. Some valuable tables of data and excellent maps of the valley of California have been issued, one of which is made use of in this paper.

The United States Government has done little more than attempt to maintain navigation. But as the relations between river improvement for navigation and drainage are so intimately connected it is impossible to leave out the work done under the U. S. Government. Under the circumstances and laws the Engineer Officers have been confined principally to removing the most prominent obstacles to navigation.

Congress has made the various appropriations aggregating $654,700.00 in a manner to merely alleviate existing troubles. No Board of Engineers has been directed to thoroughly study the problems, and devise a general plan towards which all future works should tend as far as practicable. But various bars have been reported high and have been scraped off, or a wing dam built, or a cut off made and snags removed. The result so far as the appropriations would permit have been effective. But these two rivers merit better treatment. They flow through more than a million acres of magnificently fertile swamp land, and with proper treatment would control the freights to and from market of several times this area; although they might carry but a small fraction of the gross freight moved. It is not what freight they carry that they should be credited with; *but what they cause the gross volume of freight to be carried for.*

Could Californians realize the immense value of the rivers of

this State as lines of drainage and navigation, they would guard with great care every interest connected with them, and insist that the State and General Government should do their full duty in preserving and utilizing them.

DISTRICT, CORPORATION, AND PRIVATE EXPENDTURES.

It is impossible to get full data of the millions spent by Levee Districts, Reclamation Districts, corporations and individuals. The enormous sum of $11,000,000.00 has been traced by the writer, and it is probable that this sum is not half of what has actually been spent.

On the Sacramento and its branches and on the San Joaquin, below the mouth of the Stanislaus, there are 1,270 miles of levees. (C. E. Grunsky, C. E., member Tech. Soc. P. C.)

In the lower reaches of these two rivers there are thirteen dredges at work, whose aggregate capacity is about 25,000 cubic yards per day, or over 600,000 cubic yards per month.

No where upon earth, except in the construction of the grand canals, Suez and Panama, has such a dredging plant ever been massed. Not even at the head of Chesapeake Bay did Col. Craighill assemble such a plant, although he moved 500,000. cubic yards per month. Yet this grand group of engines in the deltas of the Sacramento and San Joaquin is working without system. There are but two instances where two of them are working on the same "plan," and the greater portion of them are, or have been engaged for years in building levees at right angles to flood channels.

It is hard to realize the vast operations which this group of engines is doing. By comparison, they do more work in a month than is done by the plant operated by the Harbor Commissioners in a year. When one reviews this work and realizes that these separated, scattered operations are in one river system, and yet working independently, and frequently at cross purposes, it is hard to realize that it is directed by human intelligence, yet the men directing these separate operations are terribly in earnest; frequently every acre, every dollar they own is involved.

The 1,270 miles of levee before mentioned represented an amount of labor equally hard to realize. To review the field and ascertain that in most instances a district contains only a few miles of

levees, and that their agregate length is divided up into several hundred districts—that it is rare that the same authorities have located or controlled lines of levees immediately opposite—that (if current reports be true) one set of levees is built up a little higher than another in the hope that an opposite break may occur, or that under cover of darkness or force works have been destroyed—that bitter and life long quarrels between rival owners have determined in the location and construction of levees rather than sound engineering principles. To review all this, and see along with it the grand energy and immense sums that have been many times uselessly spent is well calculated to warn one to stand aloof from such work.

But when this review is thoroughly made, the reason of much of the failure stands out in bold lines—want of system—lack of a full conception of the work to be accomplished is stamped from end to end.

It would be impossible in the limits of this paper to review the whole system of river improvements and levees embraced in the valley of California. But the general dispositon has been to dam up, confine and obstruct the flood waters, rather than to provide adequate passageway. The entrance of the American into the Sacramento affords an example. The natural condition of this entrance was in times of flood very different from what now exists. The city of Sacramento stands across the path of American river floods, and has built its north levee in such a position as to throw the full volume of American river floods about at a right angle into the Sacramento. As a consequence no levee above the junction has ever stood, and never will stand an ordinary winter until something like the natural condition be restored, and adequate water-way be provided.

The condition now imposed puts an embargo on any reclamation of the 500,000 acres in Yolo-Solano Basin. For the flood waters of the American river being upon a grade twelve or thirteen times as steep as those of the Sacramento, easily force the latter back *up stream for miles*, and over any system of levees that can be constructed on the right bank.

Again, the combined capacity of all the various channels of the San Joaquin, in their tortuous and levee-lined condition,

have time and time again proved themselves incapable of carrying the flood volumes presented at Paradise cut, the head of the delta swamp lands. And until a straight, or nearly straight relief channel be constructed from that point to the Bay, there must always be disastrous overflows.

Again, on the Sacramento Col. Isaac W. Smith, C. E., has conclusively demonstrated that the river cannot be made to carry even ordinary floods. (See Report Sacramento River Drainage District. Sac., 1879, pp. 9–17.)

It is therefore necessary to provide additional outlet for the floods of the Sacramento. The same authority just quoted has strongly advocated a cut through the Montezuma hills into Suisun Bay, as a very admirable adjunct to a general system. (Ib. page 22.)

There are very high authorities against dividing up a river channel, and diverting the waters. But in the cases in hand this diversion has always occurred and must continue to occur. This is conclusively proved not only by the history of floods since the valleys were occupied, but by the testimony written all over the valleys by the flood lines themselves for ages past. The question of what to do with the surplus flood waters presents itself, not for discussion, but for actual solution, and the two lines of relief marked out are direct and natural.

A GENERAL SYSTEM.

To design a general system of river and drainage improvement for the lower Sacramento and San Joaquin rivers, is a less difficult task than to unite the private interests, and to consolidate into one the various little levee and reclamation districts into which the lands involved are divided.

The extent of the interests involved are of such magnitude as to warrant the aid of both the General and State Governments, and to justify private land owners in making every possible concession. So many futile attempts have been made to reclaim isolated pieces of swamp lands by local works that the general verdict would be adverse on those so called "practical results" of the past thirty years. We have had that period of systemless, wasteful years.

For the future improvement of these rivers there are three sources of revenue:

1st. The United States Government, interested in the preservation and improvement of the navigable channels.

2nd. The State (and Municipal Corporations), interested in (A) discharging the obligation of reclaiming these lands, which obligation was assumed in accepting them; and (B) in increasing her wealth by the enactment of wise laws enabling her citizens to reclaim large areas of great productiveness.

3rd. The land owners, interested in enhancing the value of the land held by them.

These sources of funds, and the ends to be accomplished, should be united. Every dollar spent should, if possible, be part of a general system, and not one dime should be spent so as to in any way impair or counteract this general system.

A third of a century of separate, individual action has resulted in the wasting, absolute wasting, of vast sums of money. The next ten years, under a proper system, can be productive of better results at much less cost.

To accomplish this:

1st. Let Congress be urged to direct that a general plan for the protection and improvement of the rivers of the valley of California be made through the United States Engineer Department, requiring the Board of Engineers designing this system to act in harmony with such laws as the State of California may enact, and with a view as far as possible of enlarging the drainage capacity of the channels.

2d. Let the State enact a law (*a*) creating a Board of Engineers, who shall devise a general system of reclamation for the valley: (*b*) requiring all works built by corporations, districts or individuals, to be in harmony with this general plan, as far as possible; and prohibiting any work from being done which would in any way obstruct the general plan: (*c*) authorizing the consolidation of all districts so as to bring them under one management: (*d*) providing an annual fund to be expended

by the Board of Engineers in constructing certain large and general portions of the plan.

When it is considered that over 1,000,000 acres of land is involved, whose minimum value, if reasonably safe from overflow, is $100 per acre, the magnitude of the interest becomes apparent.

NOTE—The writer would respectfully acknowledge his indebtedness to the following named gentlemen and others, through whose courtesy much valuable data was furnished: Mr. C. E. Grunsky, Sacramento; Mr. J. W. Ferris, Stockton; Mr. J. C. Pierson, Sacramento, members Technical Society P. C.; W. F. Peck, C. E., Marysville; Hon. John P. Dunn, Comptroller, Sacramento; Hon. W. S. Green, Colusa; Messrs. Samuel Bigelow, David Bixler, Schultz & Voorman, Dr. Wm. M. Ryer, W. C. McAfee, and Dr. Geo. A Moore, San Francisco.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(VOLUME V.—DECEMBER, 1888.)

NOTES ON EXPERIMENTS FOR DETERMINING THE RELATIVE TENSILE STRENGTH OF PLAIN AND TWISTED IRON AND STEEL BARS.

BY LIEUT. F. P. GILMORE, U. S. N.

Read December 7, 1888.

The experiments, as indicated in the annexed tables, were made to determine the difference, if any, in the tensile strength of iron or steel bars in their normal condition, or with a certain amount of twist. The bars tested in Tables I, II, and IV, were of refined iron, and in Table III, of mild steel, such as is used for rivets in the Government cruisers building at the Union Iron Works. The material was all manufactured at the Pacific Rolling Mills. In order to secure as accurate work as possible, the test pieces in each table were cut from the same bar and numbered consecutively; and after being prepared as described below, and before twisting, they were accurately measured and divided into groups of two each, according to similarity of diameters.

The testing was all done by the same person. One group of each set was twisted until the pieces broke, as a guide for the amount of twist to be given to those to be tested for tensile strain.

The torsional strength of square and round bars being as the cubes of their sides and diameters respectively, three-quarters inch bar was used in all cases, for similarity of results.

It was shown by the experiments in Table IV, that square bars when tested without shoulders (See figure, Table II), invariably broke in the clamps of the testing machine. Therefore,

in the second set of experiments, with square bars (Table II), they were slotted on two opposite sides to a depth of one-sixteenth inch, in order to determine the breaking point between the shoulders. The round bars were all turned down about one-sixteenth of an inch on the twisted portion. In I and II the length of the twisted part is eight inches, in III and IV it is twelve inches.

The testing, as shown in III and IV, the first made, was not satisfactory for several reasons, as given above.

From each lot, two pieces without twist were tested for tensile strength and ductility, as shown in the tables. The two in each of the groups were then carefully given a number of turns in a lathe worked by hand power. In placing the twist, one end of the test piece was held fast, the other being clamped to the face plate of the lathe. The twist was then made from the end next the lathe, and at first it seemed to be a decreasing one toward the other end of the bar. But when all in, no difference in the pitch of the twist could be measured. In some of the round specimens, measurements were taken to discover any difference in the diameters after twisting, but the results were doubtful. There is a certain distortion of the pieces, both in sectional area and longitudinally, but this was probably due to the difficulty of holding the pieces in a fixed longitudinal position while being twisted. Unwin states: "There is no difference in length or in transverse section after torsion."

Measurements for ductility and reduction of area were made only on the untwisted bars, to show the general quality of the material. An attempt was made to determine the elastic limit of the twisted bars, but they all appeared to have a certain spring in them due to the twist, and the results were thrown out as unsatisfactory.

The testing was all done on the same day that the twist was placed in the bars. Results differing to some extent would probably be had were the bars allowed to rest for some time after twisting. It is well known that a new molecular condition establishes itself in iron or steel that has been allowed to rest for a period after being worked. But it is not probable that the relative value of the results would be changed.

The first strain was well within the elastic limit, about 20,000 pounds to the square inch. Weight was then added of about

3,000 pounds per square inch, at intervals of about 20 seconds, until 50,000 pounds was reached, when the pieces were broken by the addition of about 1,000 pounds per square inch until near fracture, when small increments were added.

As stated above, the results in I and II are the most complete, although the tests in III and IV were carefully made. It is unnecessary to refer to the change in tensile strength of the bars, as it is shown in the tables. A brief reference will be made, however, to the behavior of a few of the pieces. In IV, when the square bars were tested without shoulders, all broke in the jaws of the machine, as did also some of the pieces with shoulders, in Table II.

With two sides of the bar slotted to a depth of one-sixteenth inch, and a width, say, of 0.750, as in Table II, we have an area of .094 square inches taken from the bar. With a tensile strength of 55,000 pounds per square inch, this gives a value of at least 5,000 pounds which the bars have gained in strength, when they broke in the clamps. The bars were so held that these fractures were not due to compression in the jaws of the machine. Several of the bars which broke in the clamps were rebroken (No. 9 in I, a second time rebroken), and always gave an increase of tensile strength. Numbers 8 and 10 in I, broke with no snap, and seemed in a manner to twist off rather than pull apart. No. 4 in II, had a long crack in it, due to the lamination of the iron, but the results of pieces 2 and 4, same group, are similar. Attention is called to the number of turns required to break the steel bars—thirteen.

In the steel bars more satisfactory results would have been obtained had more twist been given to some of them. But III and IV indicate the same general law as I and II.

Bare results are given above, and it is left to members of the Society to determine reasons. Prof. Thurston and Commander Beardsley, of the Navy, each observed that if a ductile material is subjected to a stress beyond its elastic limit, but not beyond its tensile strength, and then allowed to rest for a time, a subsequent test will give a largely increased elastic limit and tensile strength. Similar effects are probably determined in the bars by torsion.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

PROCEEDINGS.

(VOLUME V.—NO. 4.—1888.

MINUTES OF MEETINGS.

REGULAR MEETING.

November 2, 1888.

Vice-President Molera in the Chair.

President Marsden Mansen read a paper on "The Swamp and Marsh Lands of California."

A discussion followed the reading of the paper.

Mr. Wagner said: The paper admirably illustrates what has long been known to the engineers, viz: that political engineering is always an expensive way to accomplish a given result.

Looking at the paper as an exposition of bad methods and poor results, it must certainly serve a useful purpose in aiding reform. The question of the reclamation of swamp lands and the regimen of the rivers cannot be settled in a day; the public must be educated up to the point to realize that any effective plan must deal with the storage of the waters in the mountain regions, and thus control and equalize the discharge of the streams and arrest the detritus already in the streams and awaiting an unusual flood to dislodge it. Unless this is done, the beds of the rivers in the valleys must inevitably be raised, and thus entail greatly increased expense for the future care of the levees. I think it would be wise for the Society, through a committee, to confer with the Commission of U. S. Engineers, charged with the examination of kindred subjects in this State, and thus assist in forming a proper public opinion, which must be had before any real reform can be commenced.

Professor L. J. LeConte said: I am rather inclined to favor the drainage cut through the low land back of the Montezuma hills. Mr. Isaac Smith, C. E., seems to have given the question much study, and in his reports to the Sacramento Drainage Commission has clearly shown its practicability and capacity for relieving the district whose flood waters now escape through Cache Slough. If this scheme be properly carried out, I am of opinion that the flood-water capacity of the Sacramento River will be greatly enhanced. As a result, the river would more rapidly flush out the great volume of sand now choking the channel ways, and navigation would be greatly benefited. People outside of our profession have no adequate idea of the extent of sandy deposits in the lower river, and its hurtful effects on the capacity of the channels. I would simply call your attention to the potent fact that, as a result of this filling, the tidal influences have been slowly retreating down river, and at the last examination, made in 1879, had reached a point 60 miles further down river than was formerly the case.

The Treasurer presented the following report, which, on motion of Mr. Manson, was referred to the Finance Committe:

November 2 1888.

MARSDEN MANSON, President:

Dear Sir--I have the honor to make the following report of the financial condition of the Technical Society:

Feb. 29, 1888—received from outgoing Treasurer	$ 317 50
Have made collections to date as follows:	
Dues for 1887	57 00
Initiation fees	20 00
Dues for 1888	842 00
Total	$1,236 50
Disbursements as per vouchers—	
Rent	$ 200 00
Printing	563 94
Petty Expenses	34 85
Collections	47 75
Janitor	35 00
Amount on hand	354 96
	$ 1,236 50

Yours truly,

ERNEST L. RANSOME, Treasurer.

REGULAR MEETING.

December 7, 1888.

President Manson in the Chair.

Mr. E. J. Molera, on behalf of his committee, presented the resolutions of respect to the memory of the late George J. Specht, in a handsome binding.

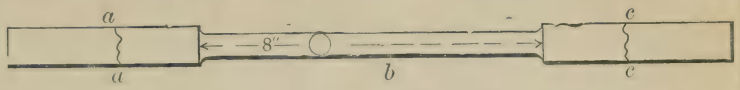
On motion, a vote of thanks to the Secretary of the Academy of Sciences, who had executed the pen work on the resolutions, was passed.

A Nominating Committee to present the names of officers for the ensuing year was appointed, consisting of Messrs. Behr, Gutzkow, von Geldern, D'Erlach and Kower.

Lieutenant Gilmore, U. S. N., gave the results of a series of experiments made by him on the relative tensile strengths of twisted and untwisted iron and steel bars.

Professor Keith gave a description of a new electric motor developed by him at his factory.

I. IRON THREE-QUARTER ROUND, LENGTH OF TWISTED PART EIGHT INCHES.



Number,	1	3	2	4	6	7	8	9	10	11	5	12
Twist in Turns,	0		½		1		2		2½		4¼	5½
Diameter	.719	.719	.718	.718	.719	.719	.718	.720	.719	.719	.705	.713
Area,	.4060	.4060	.4049	.4049	.4060	.4060	.4049	.4071	.4060	.4060	.3904	.3993
Tensile Gauge,	22,000	22,000	23,900	23,900	*25,600	26,000	26,200	*26,400	26,400	Twisted until Broken.		
Tensile, Square inch	54,180	54,180	59,020	59,020	63,000	64,000	64,700	64,800	65,000			

* Broke in clamps of testing machine at "a a." No. 6 broke again at "b" at 66,000 pounds per square inch. No. 9 broke again in clamps at "c c" at 66,800 pounds per square inch, and again between shoulders at 67,300 pounds per square inch.

No. 1 Elongated in 8 inches 25.37%. Reduction of area 41.5%.

No. 3 Elongated in 8 inches 27.75%. Reduction of area 41.5%.

II. IRON THREE-QUARTER SQUARE, LENGTH OF TWISTED PART EIGHT INCHES.

Number	3	5	1	6	2	4	7	12	10	11	8	9
Twist in Turns	0		¼		½		1		1½		3	2½
Width	.752	.751	.752	.749	.752	.751	.752	.753	.750	.753	.750	.753
Thickness	.614	.615	.606	.618	.625	.617	.623	.616	.620	.620	.611	.620
Area	.4617	.4618	.4557	.4629	.4700	.4634	.4685	.4638	.4650	.4667	.4582	.4667
Tensile Gauge	25,900	25,200	26,400	26,200	27,200	27,000	30,000	*30,300	*30,800	30,000	Nos. 8 and 9 twisted until broken.	
Tensile, Square inch	56,090	54,560	57,930	56,600	57,900	58,260	64,000	65,330	66,230	64,280		

* Broke at "s s." No. 10 broke again at shoulder "s s" at 67,520 pounds per square inch.

III. STEEL THREE-QUARTER ROUND, LENGTH OF TWISTED PART TWELVE INCHES.

Sectional Area, 0.3696 in. All pieces broke between shoulders.

Twist in Turns	0	⅛	¼	½	13
Tensile, Square inch	57,090	57,630	57,630	59,250	Broke.
Tensile, Square inch	57,630	57,900	51,900	57,360	Broke.

Elongation in 12 inches 28.33%, = 32.75% in 8 inches.

IV. IRON .76 IN. SQUARE; AREA .5776; NOT DRESSED.

All twisted pieces broke in clamps.

Twist in Turns	0	⅛	¼	½	7 and 11
Tensile, Square inch	52,460	54,190	53,150	53,670	Two pieces.
Tensile, Square inch	52,630	*53,670	53,670	†58,860	

Elongation in 12 inches = 27.33%.

* Broken again at 55,920 pounds per square inch.

† Broken again at 60,000 pounds per square inch.

+ W. SR 2nd
ps. XO net

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